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CONTENTS

The American Association for the Advancement of Science:—

A Geologic Forecast of the Future Opportunities of our Race: PROFESSOR T. C. CHAMBERLIN 937

The Thesis of Modern Logistic: PROFESSOR CASSIUS J. KEYSER 949

Chemistry at Harvard University 963

Scientific Notes and News 964

University and Educational News 966

Discussion and Correspondence:—

"Official" List of Zoological Names—An Open Letter to Professional Zoologists: DR. CH. WARDELL STILES. *Glacial Clays of the Maine Coast:* ROBERT W. SAYLES 967

Scientific Books:—

Harker on the Natural History of Igneous Rocks: PROFESSOR FRANK D. ADAMS. *The Voyage of the Belgica:* DR. WM. H. DALL.. 968

Special Articles:—

Preliminary Note on the Chromosomes in the Oogenesis, Fertilization and Cleavage of Certain Hemiptera: DR. C. V. MORRILL .. 970

Societies and Academies:—

The American Physical Society: PROFESSOR ERNEST MERRITT. *The Geological Society of Washington:* PHILIP S. SMITH, FRANCOIS E. MATTHES. *The Philosophical Society of Washington:* R. L. FARIS. *The Society for Experimental Biology and Medicine:* DR. EUGENE L. OPIE. *The Northeastern Section of the American Chemical Society:* K. L. MARK 971

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A GEOLOGIC FORECAST OF THE FUTURE OPPORTUNITIES OF OUR RACE[1]

To those organizations that are struggling with the presidential problem, from Central American republics to social clubs, one may cordially recommend the unique practise of this association, for the adroitness with which it makes the presidential office go twice as far as is usual, while at the same time it reduces the hazard of the association to the lowest terms. Near the close of an annual session a president is chosen and is at once permitted to enter upon the annual functions of the office by attaching his signature to certificates of membership, which it is assumed he is competent at once to do, but he does not enter upon any conspicuous or presentative functions so unpreparedly; the retiring president holds the stage for the succeeding year. At the next annual session, after a year of manual practise exercised on relays of certificates that come at close intervals, the incoming president is formally introduced to the association and assumes the chair. During this session he responds to addresses of welcome and presides over the general sessions of the association with as much grace and dignity as he may be able to command, but beyond this he has no specific occasion, nor does the association assume any responsibility, for anything that might betray scientific attainments or the possession of opinions. Near the close of the session, a new president is chosen, and the active president enters upon his career as retiring presi-

[1] Address of the president of the American Association for the Advancement of Science, Boston, December 27, 1909.

dent. At the end of the year he is thought to have retired so far that he may safely be permitted to say what he wishes on some subject of his choice without undue hazard to the association. This permits him to deliver himself with a large degree of freedom. If he shall say anything amiss, the burden thrown on the association is merely the reflection that at an earlier stage in the evolution of the association, now lapsing into dimness of memory, an unfortunate selection was made.

The established custom of occasions of this kind leads the association to expect that its retiring president will address it upon some theme connected with the field of his own work. I shall not altogether ignore this custom, but I have chosen a theme that is at once peculiarly humanistic and distinctly prophetic. Geology has not usually been regarded as in any special sense a humanistic science, much less a prophetic one. But it is just because it has not been so regarded and because I have fondly dreamed that it might become tributary in an eminent degree to humanistic problems and to a prophetic insight that I have chosen the theme assigned for the evening.

Ever since the race came to a virile state of intelligence, it has tried to peer into the future that it might guide itself by its foresight. Now and then it has prolonged its vision beyond mere temporary concerns and has endeavored to prophesy the end of the race and the destruction of the earth. At all stages the depth of its vision into the things before has been close akin to the length of its vision backward and to the depth of its insight into the things about it. The lamp of the past and the illumination of the present have been its light for the future. This must doubtless always be its true method, for only as the race sees far into the past, sees widely and deeply into the present, has it any firm basis for a confident prophecy of the future. Even in its early days, the race did not fail to note that—though this may not be so of the ultimate entities—the existing *forms* come into existence, live their day and pass away; why not, therefore, the race and the earth on which it dwells? Even as the race grows into its fuller maturity and the horizon of its vision is enlarged, there will doubtless still remain the conviction that there has been a beginning of the current order of things, and a like conviction that there will be an end. The enlargement of vision will only serve to bring into view an additional multitude of organisms and organizations that have come into form, endured for a time and passed away. Any future change in human forecasts is not likely to be one of method, but one of measure. Some of the features that have entered into former prophecies will no doubt disappear and perhaps new ones be added. The forecasts of pre-scientific times often made the doom of the earth hinge on some lapse in the conduct of man—made a physical disaster serve as a moral punishment. With a better knowledge of the moral law and of man's place in nature, this anthropic view will no doubt give place to a more consistent insight into the sequences of the moral and the physical worlds.

In the earlier days of the race the backward look was short and the putative origin of the race and of the earth was placed but a few thousand years in the past; in consonance with this, the forward look placed the end not far in the future. So too, as the beginning was made chaotic, the end was made cataclysmic.

The dawn of the earth sciences was followed by a new forecast, and as these sciences grew this underwent revisions and recasts. It was learned that the history of

the earth stretches back not merely for thousands but for millions and tens of millions of years; that the on-goings of the earth are actuated by energies too broad and deep and strong to be swerved in their course or brought to an end by the acts of those who dwell upon it; that the march of earth-history has a mighty tread not to be measured by the merits or lapses of even our favored race.

The trend of prophetic thought in the last century invites a closer review. The basis of forecast lay fundamentally in the mode of origin assigned the earth and in the general trend of its past history, especially the trend of those agencies that controlled the conditions of life on its surface. The solar system was thought to have had its origin in a gaseous or quasi-gaseous nebula. The earth, as a member of the solar system, partook of this origin, and was conceived to have been, at an early stage, itself a fiery, gaseous globe. It is not needful here to review the special hypotheses or pay honor to their great authors from Kant and Laplace to Lockyer and Darwin, for the sole feature that potentially shaped the history of the earth was the early gaseo-molten state in which they essentially concurred. An alternative was indeed offered in the suggestion that the earth might have grown up by the accretion of small bodies but it was then held by students of dynamics that such an origin was inconsistent with the symmetry of the system and the rotations of the planets, and so an origin in the gaseous or quasi-gaseous form was almost universally accepted, as by compulsion. Later, the gaseous earth, by cooling and condensing, was thought to pass into a molten sphere wrapt in a hot vaporous atmosphere. This atmosphere was vast because the conditions required it to contain all the water of the globe and all the volatile matters that have since entered into the waters and the body of the earth. At a later stage a crust was logically made to form over the molten sphere and the waters to condense upon it, swaddling the entire globe perhaps in a universal ocean. By further cooling, shrinkage and deformation, the waters were thought to be drawn into basins, the land to appear and the history of the stratigraphic record to begin. It is important to note that the main agency in this hypothetical history was loss of heat; and so, with consistent logic, loss of heat was made to lie at the bottom of the great events of the earth's subsequent history and, in the forecast, to be the chief cause of its doom. From a plethora of heat, of air and of ocean, putative loss followed loss in the past, and by prophecy loss is to follow loss in the future until emaciation, drought and frigidity mark the final state and the end of all life. As the body of the earth cooled and shrank and permitted penetration, the ocean was made to enter it and by union with its substance was thought to have been suffering loss in the long past and to be doomed to further losses yet to come. By a like union of the constituents of the air with the body of the earth, as time went on, the great smothering atmosphere of the primitive days was supposed to be brought down first to compatibility with marine life, later to the lower land life and still later to the higher air-breathing forms. Projected logically into the future, still further depletion of the vital constituents even to the verge of exhaustion, attended with pauperization and finally with extinction of life, entered into the forecast. With the gathering of the oceans more and more into the basins and their absorption into the body of the earth, with the persistent consumption of the atmosphere and with the progressive cooling of the whole, the moisture of the air was thought also to have grown less and less. At first a deep,

warm mantle of vapor and cloud hypothetically clothed the whole earth, and even half way down the geologic ages was thought to have enshrouded the globe and to have given warm, sultry climates to all latitudes. But this mantle at length was made to give place to rifted clouds and clearer skies, and later on to mild aridities followed at length by desert stages which are even now supposed to be creeping out persistently on the once fertile lands. Thus we reach our own times at a putative stage when heat and air and moisture are running low; thus the predestined end is foreshadowed in the not distant future.

The round conception of the history shaped it as a progress from excess to emaciation, a sliding down the scale; it made the life history but an episode intercurrent in the great decline from the too hot and the too much to the too cold and the too little.

The logic in all this is plausible. Starting with the hypothetical premises, the conclusions seem to follow. Variations of detail might well be found in the complexities of the case. Especially might sources of supply be assigned to offset waste and loss in some degree, but granting the premises the conclusion is not easily escaped. In point of fact the general conception dominated the geologic thought of the last century. Not only this, but in no small degree it gave direction to the interpretations and in some measure even influenced the observations of geologic phenomena well down to the close of the century and is far from obsolete to-day.

But logical and plausible as was this general conception of earth-history, it was hung, as you have not failed to notice, on the hypothesis of the genesis of the earth accepted. However logical, its logical strength was only that of the hypothesis on which it was hung. I say its *logical* strength advisedly, for outside the logic of the general concept there was always the appeal to the concrete evidences of the geologic record. This appeal was made, and was thought to be on the whole confirmatory. The strata of high latitudes were found to contain relics of life of tropical or sub-tropical types, not only in the early stages but well down toward recent times. Figs and magnolias grew in Greenland as late as the Tertiary period. Phenomena so striking gave deep hold to the logical scheme. Phenomena not so consonant with it were easily overlooked or lightly passed by as is our wont when too much impressed by what *must* be true. It is, however, a merit of modern science that it puts that which *is* to the front and that which logically *must be* in a secondary place. And so during the past century inconsonant data were gathered with the consonant. Most of the inconsonant facts were of the unobtrusive sort, but yet some of them were startling, were seemingly incredible, were indeed long doubted and only slowly gained credence. The accumulation of this inconsonant data gradually weakened the hold of the general logical concept and prepared the way for a reconsideration.

Meanwhile a serious source of doubt had arisen on the logical side, from the progress of physics. The older hypotheses of the origin of the earth had been framed before the kinetic theory of gases was evolved. After the kinetic view was accepted it was pointed out by Johnstone Stoney that the velocities of the molecules of the outer air place a limit to the volumes which planetary atmospheres may possess. When the test which this suggested was applied to the postulated atmospheres and voluminous gaseous states of the early earth, it gave rise to grave doubt as to the physical consistency of these conceptions.

Weakness also arose in another quarter. One of the main props of the gaseous or quasi-gaseous hypotheses was, as already remarked, the general conviction based on dynamical grounds that condensation from any other nebulous state than gaseous or quasi-gaseous would give revolutions and rotations to the planetary system at variance with those actually possessed. A reexamination, however, near the close of the century, developed grounds for the conviction that a gradual gathering in of matter from a scattered orbital state would give rotations and revolutions quite as well in accord with the facts formerly known and seemingly even better in accord with new facts recently brought to light.

Thus toward the close of the last century there arose from different quarters cogent reasons for a reconsideration of the prevailing general view, and with it a recast of the former forecast. Further scrutiny added new doubts to those that had previously arisen and in the end the verity of the older hypotheses of genesis was challenged and new conceptions based on orbital dynamics, in contrast to gaseous dynamics, were offered in their stead.

It is not appropriate for me to say that this challenge was successful, or that the older conceptions of the earth's origin are to be laid on the shelf. As an advocate of the method of multiple working hypotheses it belongs to me to beg of you to save and to use, so far as you can find use in them, all the hypotheses that seem to you to be capable of working at all. Much less would it be appropriate for me to affirm that any form of the newer conceptions is entitled to take the place of the older in your complete confidence. The final adjudication of genetic hypotheses can only come of long and patient trial by searching analysis, by scrutinizing logic and by application to the multitudinous phenomena which not only the earth, but the solar and stellar systems present. It is sufficient warrant for the present review, however, that not a few of the more incisive students of these things have been led to seriously reconsider the foundations of the hypotheses of earth-genesis that have been offered, old and new, and to examine with renewed care the interpretations and inferences that have been made to hang upon them. Whatever may be your personal leanings you will no doubt agree that it seems less laudable now to hang prophecies of the future upon hypotheses of genesis, than when certain of these hypotheses received the almost universal assent of those then best qualified to hold opinions respecting them.

It does not seem to be going too far, moreover, to say that whereas we seemed to be shut up to hypotheses of genesis that gave the earth a gaseo-molten state at the start, it now seems, to some students at least, possible that the earth inherited a quite different state from a slow growth from planetesimal or other accretions. If diverse views are thus permissible they offer alternative working conceptions and thus help to give freedom of interpretation while they stimulate observation on the critical phenomena. We may therefore be permitted first to review the states assigned the early earth by the competitive genesis offered and then the critical phenomena that bear upon the earth's future.

Quite in contrast with the older pictures of a primitive earth cooling from a gaseous state, the planetesimal hypothesis, which may be taken as representative of theories based on concentration from a dispersed orbital state, postulates a solid earth growing up slowly by accessions and becoming clothed gradually with an atmosphere and a hydrosphere. Each of the fundamental parts, the earth, the air and the water, is

made to grow up thus together from smaller to larger volumes, without necessarily attaining at any stage a very high temperature. The early sources of growth for the atmosphere and the ocean, though reduced in later time, continued to serve as sources of replenishment when the familiar agencies of loss came into play in the later ages. Thus, far from assigning at the start a vast atmospheric and oceanic supply, and assuming progressive depletion of this with the progress of time, the newer view starts with a minimum supply and rests on means of feeding which are held to run hand in hand with the sources of loss and to more or less completely compensate them in a varying way. The question of the future under this view is, therefore, not how long beyond the present day will the original supply last, but rather how long will the oscillating compensation of loss and supply remain effective? Or in other words, how long will the past degree of equilibrium between the opposing agencies keep the critical conditions within the limits required by life? This question turns us quite away from any serious dependence on the original states and centers attention on the geologic record and on the potency of agencies still in action. Are the chief agencies which have controlled life conditions for tens of millions of years past still in good working order and likely to continue effective for a long era yet to come, or do they show clear signs of declining power portending an early failure? Let us enter a little closer into the consideration of the specific factors on which life depends, though time will not permit us to go far.

The pre-scientific fear that the end of life will come by cataclysm is not yet obsolete, nor is it theoretically impossible, but violent agencies are among the least to be feared. Life might indeed be imagined to be in jeopardy from volcanic and seismic convulsions but they really offer no serious menace to life in general, and they appear never to have done so in the known ages. The deadliness of these boisterous catastrophies impresses itself unduly on the emotions. The real peril, if peril there be, lies in the deadly unbalancing of agencies of the quiet sort.

The conditions essential to the maintenance of the habitability of the earth are many, but the more critical factors either lie in the atmosphere itself or are intimately associated with it. The point of keenest interest is the narrowness of range to which these mobile factors are confined. The several constituents of the atmosphere might each or all easily be too scant or too abundant. In a peculiar sense is this true of the carbon dioxide which, though one of the least, is preeminently the decisive constituent of the atmosphere. A small proportion of carbon dioxide is essential to plant life and so to animal life, while a large proportion would be fatal to air-breathing animals. If the three or four hundredths of one per cent. now present were lost, all life would go with it; if it were increased to a few per cent., the higher life would be suppressed or radically changed. And yet, on the one hand, the theoretical sources of supply are abundant, while, on the other, the agencies of depletion are efficient and active. There is little escape from the conclusion that ever since the birth of air-breathing life, some 30,000,000 or 40,000,000 years ago, let us say, the interplay of these agencies of supply and depletion has been so balanced that neither fatal excess nor fatal deficiency has been permitted to cut short the history of the higher life.

The dangers of excess or deficiency of the other constituents of the air are indeed less narrow when named in percentages,

but they are scarcely less real in theoretic possibility.

The well-being of life is hemmed in between a suitable proportion of moisture in the air dependent on a competent area of water-surface to supply it, on the one hand, and a diluvial excess of water, on the other. Universal deluges and universal deserts would alike be disastrous. A few thousand feet more of water-depth or a few thousand feet less would alike seriously restrict the class of life to which we belong.

In even a more serious way the habitability of the earth is conditioned on a narrow range of mean temperature—a range, roundly speaking, of 100° Centigrade. This is scarcely 5 per cent. of the range of natural temperatures on the earth and a still smaller per cent. of the range of temperatures in the heavens. A few miles above us and a few miles below us, fatal temperatures prevail. It is profoundly significant that the thermal states of the narrow zone of life on the face of the earth should have been kept within so close variations as to permit the millions of species forming the great genealogical lines leading up from the primitive types to have perpetuated their lineages in unbroken continuity for such ages, while the prevalent temperatures a few miles above them or a few miles below them, as well as in space generally, would have been fatal. While the necessary heat is dependent on the sun, this control of temperature seems to have been intimately related to the atmosphere and is a further index of its specially critical functions.

To appreciate the full significance of the control of life conditions within these narrow limits when the possibilities were so free and so wide, there is need for some tangible index of the time, but there are at present no means for the close measure of the geologic ages, merely rough estimates of the order of magnitude. Life was far advanced when a readable record first began to be made; but yet since that record began, at least 100,000 feet of sediments—not to choose the largest estimates—have been laid down by the slow methods of wash from the land and lodgment in the basins. The estimate of the years thus represented has been put variously from 50,000,000 to 100,000,000, with indeed higher figures as well as lower. Merely to roughly scale the order of magnitude, and without pretense of accuracy, let us take the midway figure of 75,000,000 years as representative. Let this be divided into fifteen periods of 5,000,000 years each and these will roughly represent the technical "periods" of geologists. By this rough scale we may space out such of the great events as we need now note.

Slight and changeable excesses of evaporation over precipitation and the reverse prevail widely, but only intense and persistent aridity gives rise to thick deposits of salt, gypsum and other evaporation products over large areas—with perhaps some exceptions—for in nearly all large natural basins the area that collects rainfall is notably larger than the closed basin within it that alone can retain water for continuous evaporation. It is therefore fairly safe to infer clear skies and pronounced aridity when beds of salt and gypsum occur over large areas, especially if accompanied by appropriate physical characters and by such types of life only as tolerate high salinity, or show pauperization, or by a total absence of life.

Now extensive deposits of salt and gypsum are found in the Salt Range of India, in strata of the Cambrian period, the earliest of the fifteen that make up our rough scale of 75,000,000 years. Because these lie so near the beginning of the geologic record they afford a singularly in-

structive insight into the conditions of the atmosphere well back toward its primitive state. They challenge at once the view that in those early ages the earth was swaddled by a dense vaporous atmosphere from pole to pole; for under such a vaporous mantle a great desert tract in India would be scarcely credible.

If we come forward in time two periods, to the deposits of the Silurian stage, we find that underlying the basin of the St. Lawrence in New York and westward there stretch great sheets of salt and gypsum, many thousand square miles in extent. These beds are accompanied by complete barrenness of life in some parts, by pauperization of life in other parts, by selections of life according to tolerance of salinity in still other parts, and by harmonious physical characters, all of which combine to add strength to the interpretation. All these imply a degree of aridity approaching desert conditions in what is now the well-watered region of our Great Lakes. These signal facts join those of the Salt Range of India of earlier date in challenging the former conception of a universal envelope of vapor and cloud in all those early times.

In the next period there are formations that have been interpreted as implying desert conditions, but perhaps on less firm grounds, and we pass on to certain stages in the sub-Carboniferous period next following, wherein beds of salt and gypsum are found in Montana, Michigan, Nova Scotia and Australia, which imply like climatic conditions. If we pass on to the Permian and Triassic periods, near the middle of the geologic series, beds of salt and gypsum are phenomenally prevalent on both the eastern and western continents, reaching through surprising ranges of latitude. The relative paucity, as well as the peculiar characteristics of the life of those times, seems equally to imply vicissitudes of climate in which scant atmospheric moisture was a dominant feature. There seems no tenable way to interpret these remarkable facts of the middle periods except by assuming an even greater prevalence of aridity than obtains at the present time. So, at times in the later periods, but at times only, the stratigraphic record implies atmospheres as arid as that of to-day, not everywhere, indeed, but in notable areas and in certain horizons.

These and other significant facts of consonant import form one group of phenomena.

If, on the other hand, the record be searched for facts of opposite import, they will come easily to hand. Starting near the beginning of the record, it is even more easy to find stages abounding in evidences of prevailing humidity, of great uniformity of climate and of most congenial life-conditions reaching through wide ranges of latitude. If we rested on this selection alone, the old view would be abundantly sustained; but the strata bearing evidences of aridity lie between these. Combining the two sets of facts, the conception seems to force itself upon us that from the very earliest stages of the distinct life-record onward, there have been times and places of pronounced aridity much as now, or even more intense, while at other times, intervening between these, more humid and uniform conditions prevailed.

This conception grows in strength as we turn from atmospheric states to prevailing temperatures. The body of scientific men have rarely been more reluctant to accept any interpretation of geologic phenomena than that of recent general glaciation on the lowlands of Europe and America in mid-latitudes when that view was first advanced by Louis Agassiz. With the conception of former pervasive warmth then

prevalent, it seemed beyond belief that great sheets of ice could have crept over large portions of the habitable parts of Europe and North America some thousands or tens of thousands of years ago. Belief in this was made easier, however, by the view also then prevalent that the earth had been greatly cooled in the progress of the ages, that the atmosphere had been much depleted by the formation of coal, of carbonates and of oxides, that the ocean had been reduced by hydration and entrance into the earth, and that thus a stage had been reached that made possible an epoch of depressed temperature and of glaciation. The ice age, thus theoretically associated, came to be widely regarded as but the first stage in a series of secular winters destined to lead on to the total refrigeration of the earth. This view was abetted by the theory of a cooling sun. The depleting and the cooling processes were regarded as inevitably progressive, and the final doom of the earth as thus foreshadowed in the near future, geologically speaking.

But opinion was scarcely more than adjusted to this view when the geologists of Australia, of India and of South Africa, severally and independently, and later those of South America presented evidences of former glaciation over extensive areas in those low latitudes. The typical marks of glaciation were indeed traced even up to and a little across the tropical circles from the south, in Australia, and from the north, in India. Moreover, all these were reported from strata of Permian or late Carboniferous times, *i. e.*, from the sixth or seventh of the technical "periods." For a score of years the body of geologists not in immediate contact with the evidence itself, doubted the interpretation, but the growing evidence grew at length to be utterly irrefutable. There seems no rational escape from the conclusion that mantles of ice covered large areas in the peninsula of India, in Australia, in the southern part of Africa, and in South America, close upon the borders of the tropics, at a time roundly half way back to the beginning of the readable record of life.

On the basis of similar evidence Strahan and Reusch have announced glacial beds in Norway at a horizon much lower but not closely determinate. Willis and Blackwelder have described glacial deposits of early Cambrian age in the valley of the Yangtze in China in latitudes as low as 31°. Howchin and David have described glacial formations of similar age in Australia. In the last two cases the glacial beds lie below the strata that bear the Cambrian trilobites; in other words, they lie at the very bottom of the fossil-bearing sediments, fifteen periods back, or 75,000,000 years ago on our rough scale. Professor Coleman has offered what he deems good evidence of glaciation much farther back at the base of the Huronian in Canada, but some skepticism as to its verity has yet to be overcome.

Even more pointedly than the epochs of aridity, do these early epochs of glaciation seem incompatible with the view of a hot earth universally wrapt in a vaporous mantle in early times. They favor the alternative view of merely temporary localized intensifications of climate which life was able repeatedly to survive. This seems to warrant the belief that life may survive similar intensifications again and again in the future.

At present polar and alpine glaciation are contemporaneous with aridity. There are reasons for thinking that the past glaciations and aridities were in some similar way correlated and that they cooperated to give vicissitude to the climates of certain geologic epochs. The known epochs of glaciation, however, are fewer than those of aridity.

On the other hand, at several stages, as already noted, abundant life, bearing all the evidences of a warm-temperate or sub-tropical character, flourished in high latitudes. In Greenland, Spitzbergen and other Arctic islands, are found the relics of life not known to be able to live except under conditions of genial warmth. These imply former sub-tropical conditions where now only frigidity reigns.

In the light of these contrasted climatic states of aridity and glaciation, on the one hand, and of uniformity and geniality in high latitudes on the other, intervening between one another, we seem now forced to the conception of profound climatic alternations extending over the whole stretch of known geologic time. Concurrent with these alternations there may perhaps have been variations in the constitution, as there certainly were in the condition, of the atmosphere.

If we turn to the relations of the waters and the land, an analogous oscillating history presents itself. This was possibly connected causally with the climatic oscillations. At no time in the history recorded by clear geologic testimony is there proof of the absence of land, and certainly at no time is there a hint of the absence of an ocean, whatever theoretic views may be held of the earliest unknown stages.

The progress of inquiry seems to force the conviction that the land area in the earliest stages of good record was quite comparable to that of the present time, both in its extent and in its limitations. Following down the history, the land area seems at certain times to have been larger than now, while at other times it was smaller. There appears to have been an unceasing contest between the agencies that made for the extension of the land and the agencies that made for the extension of the sea. While each gained temporarily on the other, complete victory never rested with either. From near the beginning of the readable record there appears to have been an unbroken continuity of land life, and from a like early stage, an unbroken continuity of marine life. Probably the history of both goes back unbroken into the undeciphered eras which precede the readable record, and no one to-day can safely affirm the precedence of either over the other, either in time or in genesis, whatever his theoretic leanings may be.

Among the agencies that may be assigned for the extension of the land are those that deform the body of the earth, deepening its basins and drawing off the waters, while other portions are protruded and give renewed relief and extent to the land. Among the agencies that make for the extension of the sea are the girdling of the waves about the borders of the land and the decay and wash of the land surface which is thus brought low at length and covered by the advancing waters. If the deformation of the earth-body were held in abeyance for an indefinite time, the lowering of the land, the filling of the basins, and the spreading of the sea would submerge the entire land surface and bring an end to all land life. Great progress in such sea-transgressions appears to have been made again and again, until perhaps half the land was submerged, but before land life was entirely cut off or even very seriously threatened, a regenerative movement in the body of the earth intervened, the land was again extended and the sea again restricted. Here then, also, there has been a reciprocal movement which, while it has brought alternate expansions of land life and of sea life, has, notwithstanding, permitted the preservation of both, and thus maintained the continuity of the two great divisions of life.

It appears, thus, that in each of the great groups of terrestrial conditions upon

which life is dependent, there has been, through the known ages, vast as they are, an oscillatory movement which has brought profound changes again and again but has never permitted any of the disasters threatened in these movements to go far enough to compass the universal extinction of life. These reciprocal movements appear to be dependent upon a balancing of the action of agencies that is scarcely less than a law of equilibrium. It is not too much to regard this as a regulative system. A clear insight into the agencies of this regulative system is rather a task of the future than an attainment of the present, and I can only offer tentative hints of what may prove to be its main factors and beg of you to accept them with due reserve.

The preservation of the land against the incessant encroachments of the waters seems probably due to a periodic deformation of the earth-body dependent on internal dynamics not yet well understood, at least not yet demonstrated to general satisfaction. The body of the earth feeds its atmosphere through volcanic and other means. How far this is merely a return of what has been absorbed earlier it is not prudent here to say, as opinion is not harmonious on this, and the evidence is as yet uncertain. Much depends on the constitution of the earth's interior and that in turn hinges on its mode of origin. Perhaps it will be agreed generally that feeding from the interior is one of the sources of supply which offsets the depletion of the atmosphere caused by its union with earth substance, in short that the earth-body gives out as well as takes in atmospheric material. Important or unimportant as this may be, it is not apparent that there is in it any automatic balancing suited to control the delicate adjustments requisite for continuity of life. The ocean acts as an important regulator by alternately absorbing and giving out the atmospheric gases as required by the state of equilibrium between the water and the air. This action is automatic but has its limitations and peculiarities and does not seem wholly adequate. If we are able to name such an adequate automatic action at all at present, it probably lies in the molecular activities of the terrestrial and solar atmospheres and in the relations of these to the gravitative powers of the earth and the sun.

If analysis of the molecular action of the outer atmosphere be pushed to its logical conclusions, it leads to the conception of supplementary atmospheres, in part orbital, filling, in their attenuated way, the whole sphere of the earth's gravitative control. A similar study of the sun's atmosphere suggests a similar supplementary extension and this extended portion surrounds and embraces the earth's atmosphere. Under the laws of molecular activity these two atmospheres must be interchanging molecules at rates dependent on the conditions of equilibrium between them. It is reasonable that an excess in the earth's atmosphere should cause it to feed out into the sun's sphere of control more than it receives, and that a deficiency in the earth's atmosphere should cause more feeding in from the sun's supplementary atmospheres than the earth gives out. If this conception be true and be efficient, the maintenance of the delicate atmospheric conditions required for the continuity of life is automatically secured. The failure of our atmospheric supply is thus made to hang, not simply on the losses and gains at the earth's surface, but on the solar interchange and hence on the solar endurance.

The sun is giving forth daily prodigious measures of energy. The endurance of the sun is not, however, merely a question of unrequited loss, for it gains energy and

substance daily as well as loses, but so far as present knowledge goes, its gain is greatly inferior to its loss. So long as the heat of the sun was supposed to be dependent on ordinary chemical changes, or on the fall of meteorites, or on self-contraction, an activity adequate for terrestrial life could only be estimated at a few million years. But recent discoveries in radio-activity have revealed sources of energy of an extremely high order. In the light of these the forecast of the sun's power to energize the activities of the atmosphere dependent on it and to warm the earth is raised to an indeterminate order of magnitude.

If we may thus find grounds for a complacent forecast in reciprocal actions on the earth and in reciprocities between the earth and the sun, are we free from impending dangers in the heavens without?

Present knowledge points to one tangible possibility of disaster; collision with some celestial body, or close approach to some sun or other great mass, large enough to bring disaster by its disturbing or disruptive effects. Within the solar system, the harmonies of movement already established are such as to give assurance against mutual disaster for incalculable ages. Comets pursue courses that might, theoretically at least, bring about collision, but do not appear usually to possess masses sufficient to work complete disaster to the life of the earth even should collision occur, whatever local disaster might follow at the point of impact. The motions of the stars, however, lie in diverse directions, and collisions and close approaches between them are theoretically possible, if not probable, or even inevitable. There are also in the heavens nebulæ and other forms of scattered matter, and doubtless also dark bodies, which may likewise offer possibilities of collision. The appearance of new stars flashing out suddenly and then gradually dying away suggests the actual occurrence of such events. It has been even conceived that the close approach of suns is one of the regenerative processes by which old planetary systems are dispersed and new systems are brought into being. One phase of the planetesimal hypothesis is built on this conception and postulates the close approach of some massive body to our ancestral sun as the source of dispersion of a possible older planetary system and the generation of the nebulous orbital condition out of which our present system grew. However this may be, it must be conceded that in collision and close approach lie possibilities, if not probabilities, of ultimate disaster to the solar system and to our earth. But here, as before, the vital question lies in the time element. How imminent is this liability? The distances between stars are so enormous that, though they move diversely, the contingencies of collision or disastrous approach are remote. Nothing but rough computations based on assumptions can be made, but these make disaster to a given sun or system fall on the average only once in billions of years. There is no star whose nearness to us, or whose direction of motion is such as to threaten the earth at any specific period in the future. There is only the general theoretical possibility or probability. While, therefore, there is to be, with little doubt, an end to the earth as a planet, and while perhaps previous to that end conditions inhospitable to life may be reached, the forecast of these contingencies places the event in the indeterminate future. The geologic analogies give fair ground for anticipating conditions congenial to life for millions or tens of millions of years to come, not to urge the even larger possibilities.

But congeniality of conditions does not

ensure actual realization. There arise at once questions of biological adaptation, of vital tenacity and of purposeful action. Appeal to the record of the animal races reveals in some cases a marvelous endurance, in others the briefest of records, while the majority fall between the extremes. Many families persisted for millions of years. A long career for man may not therefore be denied on historical grounds, neither can it be assured; it is an individual race problem; it is a special case of the problem of the races in the largest sense of the phrase.

But into the problem of human endurance two new factors have entered, the power of definite moral purpose and the resources of research. No previous race has shown clear evidence that it was guided by moral purpose in seeking distant ends. In man such moral purpose has risen to distinctness. As it grows, beyond question it will count in the perpetuity of the race. No doubt it will come to weigh more and more as the resources of destructive pleasure, on the one hand, and of altruistic rectitude on the other are increased by human ingenuity. It will become more critical as the growing multiplicity of the race brings upon it, in increasing stress, the distinctive humanistic phases of the struggle for existence now dimly foreshadowed. It will, beyond question, be more fully realized as the survival of the fittest shall render its verdict on what is good and what is evil in this realm of the moral world.

But to be most efficient, moral purpose needs to be conjoined with the highest intelligence, and herein lies the function of research. None of the earlier races made systematic inquiry into the conditions of life and sought thereby to extend their careers. What can research do for the extension of the career of man? We are witnesses of what it is beginning to do in rendering the forces of nature subservient to man's control and in giving him command over the maladies of which he has long been the victim. Can it master the secrets of vital endurance, the mysteries of heredity and all the fundamental physiological processes that condition the longevity of the race? The answer must be left to the future, but I take no risk in affirming that when ethics and research join hands in a broad and earnest endeavor to compass the highest development and the greatest longevity of the race the era of humanity will really have begun.

T. C. CHAMBERLIN

THE THESIS OF MODERN LOGISTIC[1]

I HAVE chosen to report upon this subject because it is one in which I have found no little interest in recent years; because the thesis in question represents one among the greatest of all the triumphs of critical thought; because it possesses such high and permanent importance as belongs to intellectual activity above the levels of workaday life; because it is sufficiently new, timely and general in its appeal; and finally because, whilst it has come to be everywhere a topic of much philosophic and scientific allusion, but relatively few, it seems, have been at the pains to ascertain what the thesis precisely is.

To tell what it is, to render it intelligible not merely to astronomers and mathematicians but also to that larger class of educated folk who, as their primary interests lie elsewhere, are not accustomed to thinking much about the fundamental subtleties of logic and mathematics—*that* is one of the two aims of this address; the other one being to present, in so far as time will

[1] Address of the vice-president and chairman of Section A—Mathematics and Astronomy—American Association for the Advancement of Science, Boston, 1909.

allow, the more salient among the facts by which the thesis is supported.

It is no part of my purpose to treat the matter historically. As, however, the thesis in question is the goal and culmination of two originally independent but closely related and finally convergent movements of modern thought, I can not refrain from saying a brief preliminary word regarding each of them. They may be characteristically designated as the critico-mathematical movement and the logistical movement.

The distinctively critical spirit is not a new manifestation in mathematics. The age of Euclid was a critical age. And just now, thanks to the superb edition of the "Elements" by Dr. Heath with its wonderful richness of bibliographic citation, quotation and critical commentary, one is enabled to understand better than ever before how very fine and penetrating in fundamental questions of geometry and of logic was the thought of the age that produced the Alexandrine classic—the age, I say, for the "Elements" is to be attributed not less to the age of Euclid than to Euclid the man. But it is not of antiquity that I wish to speak. I refer to the critical movement in *modern* mathematics—to the demand for precision of concept, to the process of logical rigorization, to the sense and the craving for perfection of intellectual and scientific form, in a word, to that spirit of creative criticism which, following close upon the great Eulerian and pre-Eulerian period of discovery, manifesting itself already in the works of Gauss and Lagrange, finding powerful agencies in the analytic genius of Cauchy and Bolzano, in the geometric genius of Lobachevski and Bolyai, waxed in intensity throughout the lapsing decades of the nineteenth century, at length pervading the entire realm of mathematics like a refining and purifying fire. The result of this critical movement, thus originating in mathematics and conducted by mathematicians, was, not indeed the grounding of mathematics itself, regarded as a unitary science, but the grounding rather, upon distinct bases of postulated mathematical notions and propositions, of various great *branches* of the science; in witness whereof—to cite but one example—behold the theory of the real variable as founded by Weierstrass upon the familiar theory of the cardinal numbers assumed as certain, primordial and fundamental.

Such bases, however, were destined to appear, in the light of modern researches in another field or in what seemed at all events another, namely, the field of logic, not as constituting the foundation either of mathematics or of any of its branches but as genuine components of the superstructure. For it has ever been the faith of the logician that there are a few ideas in terms of which all definable ideas admit of immediate or mediate definition and a few propositions upon which as a basis or from which as a body of premises all demonstrable propositions admit of proof or deduction; and it has ever been the chief of the logician's problems to discover such a system of primitive concepts and propositions. It is in nothing less than a closely approximate solution of that hoary problem that modern investigations in logic have culminated. As every one knows, the conception of logic as an autonomous science is nothing new. Among the very greatest contributions of antiquity to human knowledge is the "Logic" of Aristotle. As a scientific achievement it is comparable to the "Elements" of Euclid—comparable to it also in another respect, namely, that it was not significantly improved upon for nearly two thousand years. Though always indispensable as an instrument of thought, yet logic, regarded as a science, remained stationary for so long a time, showing no

token of life, that it came to be thought of as a thing that is dead. And I suspect that even to-day there may be found scientific men of eminence who are not aware of the fact that in our time logic, as a field of research, affords a spectacle of teeming activity quite as intense as may be witnessed in physics, for example, or in astronomy or biology—men, it may be, who have yet to learn that, owing to modern logistic research, it would be as radical an error to identify the modern significance of the term logic with that of the Aristotelian system as to identify the modern meaning of the term geometry with that of Euclid's "Elements" or to identify modern jurisprudence with the code of Lycurgus or the "Pandects" of Justinian. By the logistical movement I mean the movement that began—somewhat prematurely, however, as the event was destined to show—in the logical speculations and investigations of Jungius (1587–1657), Leibniz (1646–1716) and Lambert (1728–1777); awaited the powerful impulse imparted by Boole's symbolical "Investigation of the Laws of Thought" (1854); and, under the leadership of C. S. Peirce in our own country, of Schröder in Germany, of Peano and his numerous collaborators in Italy, of Couturat, brilliant expounder and advocate of the subject in France, and of Russell, Whitehead and McColl in England, has at length produced that imposing body of doctrine now known throughout the scientific portions of the world under the characteristic name of symbolic logic.

In its present form and state of development this science is constituted of three distinct but interconnected branches: the logic of classes, which, though it corresponds to the traditional system of Aristotle, is far from being identical with it; the logic of propositions; and the logic of relations, which was originated by Charles S. Peirce, was much elaborated, refined and clarified by Schröder in the third volume of his "Vorlesungen über die Algebra der Logik," 1895, but owes its present form and conception mainly to the various contributions of Bertrand Russell in recent volumes of the *Revue des Mathématiques* (formerly the *Revista di Matematica*) and elsewhere.

For the purpose in hand the thing to be noted is the discovery of the fact that for the *notional basis* of the triple organon it was necessary and *sufficient* to assume, without definition, a very few notions—called the primitive ideas, or constants, of logic—in order that in terms of them all other notions entering logic should be definable; and that it was necessary and sufficient, for the *propositional basis*, to assume, without proof, a somewhat larger yet very small number of propositions—called the primitive propositions, or the premises, of logic—in order that by means of them all other propositions of the science should be capable of demonstration. This is not all, however; for it has been found—and here we encounter the *thesis of modern logistic*, the common culmination and result of the two movements hitherto sketched, and so a joint achievement of the logician and the mathematician, though hardly foreseen by either of them—it has been found, I say, that the basis of logic is the basis of mathematics also—that, in other words, given the primitives of logic, mathematics requires none of its own but that in terms of the logical primitives all mathematical ideas and all mathematical propositions admit respectively of precise definition and of rigorous demonstration. Accordingly, if a scientific edifice may properly be regarded as consisting of both foundation and superstructure, it becomes evident, the thesis once established, that, instead of logic and mathematics being, as hitherto supposed, radically distinct sciences, the latter is strictly

the outgrowth and prolongation of the former, and that the twain are one as the branches and upper stem of a tree are continuous with the lower stem and the roots.

To any one who knows something of the immensity of modern mathematics, something of the continent of doctrine that the term connotes, something of the countless variety and the infinite complexity of the ideas and propositions that compose the body and constitution of the science, the simple thesis in question is really astounding. And one demands that the thesis be explicated in terms in order that one may know precisely and concretely in detail what it constates. What, we wish to be informed, *are* the logical primitives that, it is alleged, are capable, though so few, of supporting so great a burden? Before attempting to meet this demand, I beg to remind you of the fact that, given a logically coherent or autonomous body of propositions, it is always in some degree a matter of arbitrary choice, though probably never one of complete indifference which of the propositions are taken as fundamental and which as derivative—that is, which are assumed and which proved. In every case the choice is to be guided by considerations of expedience, of interest, or of economy, but seems never to be coerced by necessity or by "the nature of things." Questions of relative interest, however, and of relative expedience and economy are matters of judgment. Accordingly it is not a matter for surprise that several systems of logical primitives have been devised and submitted, differing any two of them in respect of one or more elements but agreeing all of them as to the adequacy of a small number of elements, and that among investigators in the field it remains a moot question which of the systems, if any one of them enjoys that distinction in comparison with the rest, is to be preferred.

The system that I shall present here is that which Russell has adopted in his great synthesis of modern logic and modern mathematics, "The Principles of Mathematics," and which with slight modifications has been so delightfully expounded by Couturat in his "Les Principes des Mathématiques" and his "Traité de Logistique." I have thought it best to gather together all the primitive elements of the three branches of logic for compact presentation in a single uninterrupted list under their appropriate headings, reserving commentary for a subsequent stage. Moreover, despite the somewhat forbidding appearance, at first glance, of logical symbolism, I have decided to present primitive propositions in symbolic form, employing for this purpose, the symbolism of Peano slightly modified by selection from that of Schröder. Indeed this symbolism is not difficult to master; and if at first it seems a thing of so frightful mean that to be hated needs but to be seen, yet, seen often enough to become familiar with its face, we come first to endure, and then to embrace it as a convenient and potent means of clarity and economy alike of thought and of expression. It is a moot question which one, if indeed any one, of the three varieties of the logical calculus is primordial to the other two. As, however, discourse of any kind, whether about classes or about relations, would seem to be difficult if not impossible without propositions, I shall follow the leading of common sense and begin with

The Logic of Propositions.—In addition to the notions, truth and its negative, which, though they are constantly employed, seem neither to admit of effective definition nor to be strictly coordinate with any other indispensable notion, the primitive notions in propositional logic are

(1) Material Implication,

(2) Formal Implication.

And the primitive propositions are

(1) $pəq.ə.pəq$,
(2) $pəq.ə.pəp$,
(3) $pəq.ə\ qəq$,
(4) If $pəq$ and if p be true, p may be dropped and q asserted,
(5) $pəp.qəq.ə.pqəp$,
(6) $pəq.qər.ə.pər$,
(7) $qəq.rər.pə.qər:ə.pqər$,
(8) $pəp.qər.pqər:ə:pə.qər$,
(9) $pəq.pər.ə.pəqr$,
(10) $pəp.qəq\ ə:(pəq)əp.əp$,

in which, as elsewhere, p, q and r denote propositions, $ə$ (inverse of the letter c) stands for the word *implies*, pq means "p and q," while the points or dots serve the double use of denoting the word *and*, like the first dot in (5), or, like those in (1), playing the rôle of parentheses in indicating the relative ranks of the various parts of a formula. Thus, for example, (7) may be translated to read, the proposition "q implies q and r implies r and p implies that q implies r" implies the proposition "p and q together imply r"; or, in hypothetic form, if q implies q, and r implies r, and p implies that q implies r, then p and q together imply r.

The Logic of Classes.—The primitive notions in this calculus are

(1) Proportional Function, denoted by such symbols as $\phi(x)$, $\Psi(x)$, etc.,
(2) The Relation (denoted by ϵ, read *is* or *belongs to*) of an individual to a class (containing it),
(3) The notion *such that*, denoted by $\ni$ (inverse of the Greek letter ϵ).

And the primitive propositions are

(1) $k\epsilon\}x\ni\phi(x)\{ə\phi(k)$,
(2) $\phi(x) = \Psi(x).ə:x\ni\phi(x). = .x\ni\Psi(x)$.

The Logic of Relations.—In this calculus, which Russell has shown to be the logic *par excellence* of mathematics, the primitive notions are

(1) Relation, denoted as a class by rel and as individuals by such capitals as R, R', etc.,
(2) Identity, denoted by the symbol 1'.

The primitive propositions are

(1) $R\epsilon\text{rel}.ə:xRy. = .x$ has the relation R to y,
(2) $R\ni\text{rel}\ ə\exists\text{rel}\smile R'\ni(xR'y. = .yRx)$,
(3) $\exists\text{rel}\smile R\ni(\rho = \imath x.\rho = \imath y)$,
(4) $\smile\text{`}K\epsilon\text{rel}$,
(5) $\smile\text{`}K\epsilon\text{rel}$,
(6) $R_1R_2\epsilon\text{rel}$,
(7) $-R\epsilon\text{rel}$,
(8) $\epsilon\epsilon\text{rel}$,
(9) $1'\epsilon\text{rel}$,
(10) $x1'x$,
(11) $1'ə\breve{1}'$,
(12) $R\epsilon\text{rel}.xRy.y1'z\ ə.xRz$.

To the foregoing primitives must be added the notion of *denoting*, which has been made the topic of a most subtle and luminous discussion by Russell in the fifth chapter of the work above cited. The notion is that of the sense in which an individual is denoted by a concept that occurs in a proposition that is not a proposition about the concept, as "She bought *a beautiful gown*"—the thing purchased be nothing so tenuous and translucent as the concept, a beautiful gown, but presumably a concrete thing reasonably opaque.

By way of elucidating the foregoing and further sketching out the three divisions of logic, I shall now proceed to give some explanation of the primitive terms and a statement of the principal definitions and theorems composing them.

Definitions and Theorems in Propositional Logic.—The central term, proposition, is defined in terms of (material) implication, namely, a proposition is that which implies itself. The two varieties of implication are often confused and the distinction between them, being difficult to draw sharply and clearly, is to be acquired very much as a child learns to distinguish

cats from dogs. For one thing material implication subsists only between propositions while formal implication, though it is present in propositional logic, holds only between propositional functions. Now a proposition to be such must be true or else false, while a propositional function, say, x is a number, though it has the form of a proposition is not one, being neither true nor false, until the unspecified term or terms (x in the example cited) are specified and then we have no longer a function but a proposition. The implication postulated in the primitive propositions is material. The meaning of (1) is that if $p \supset q$, then $p \supset q$ is a proposition; (2) means that whatever implies anything is a proposition; and that of (3) is, whatever is implied is a proposition. Number (4), which does not admit of completely symbolic statement, is the postulate that justifies the advance from the hypothetic to the categoric—the advancement involved in passing from saying "such and such a conclusion is true *if* the premises are true" to saying, once the premises are granted true, "the proposition" (not now regarded as a conclusion) "*is* true."

One of the most striking facts in the propositional logic is the theorem that every false proposition implies all propositions and that all true propositions are implied by every proposition. The shocking character of the theorem—which refers, of course, to material implication only—disappears on reflecting that the proposition, p implies q, means simply "q or not-p"—means, that is, "q is true or p is false" and *nothing else;* for surely it is nothing shocking to affirm that a proposition that is not contradicted by any proposition in the class of true propositions is a member of the class; and that affirmation seems equivalent to asserting that "p implies q" is true unless q is false and p true. If you assert of two propositions p and q that p implies q, thereby meaning simply and solely that q can not be false and p true, then unless it happens that at once q is false and p true, there would seem to be in the arsenal of refutation no weapon with which your assertion may be struck down. The primitive propositions are some of them far from being "self-evident." It is not essential that they should be. They are chosen with reference to their sufficiency and look for justification to the body of their consequences. In these they shine—not *a priori* but *a posteriori*. Neither can they be proved true by deducing them from a theorem that is itself deduced from them—to say which is, of course, but to utter a commonplace. As an exercise, however, it is legitimate as well as interesting and instructive to assume the foregoing theorem as a postulate and as such to apply it as a test to the primitive propositions in question. Thus, to take a single example, the procedure in the case of (8) would be as follows. Let r be true and p and q either or both be false or true; then $q \supset r$ is true, hence $p \supset .q \supset r$ is true, hence (8) is true. Let r be false and p and q be true; then $p \supset p$ and $q \supset r$ are both true, pq is true, $pq \supset r$ is false, hence what precedes the colon is false, hence (8) is true. And so on for the remaining possible suppositions respecting p, q and r.

Two propositions are *equivalent* if each implies the other, and we write $p = q$. Two propositions are equivalent when and only when both are true or both are false. The fundamental operations of propositional *multiplication* and *summation* are definable as follows: We may first define the *logical product* of the two *special* propositions—a is a proposition, b is a proposition—to be the proposition, a is a proposition and b is a proposition. Then, denoting this special product by $a \supset a.b \supset b$,

the logical product, pq or $p \sim q$, of *any* two propositions, p and q, may be formally defined by the definition:

$$p \supset p . q \supset q . r \supset r . \supset : pq = : p \supset (q \supset r) . \supset r.$$

This definition of the notion—vulgarly called the joint assertion of p and q—may be rendered thus: p, q, r being propositions, the product of p and q is the proposition—any proposition r such that p implies that q implies it, is true. The *logical sum*, $p \sim q$, of two propositions p and q admits of the definition:

$$p \supset p . q \supset q . r \supset r . \supset : p \sim q = : p \supset r . q \supset r . \supset r ;$$

that is, p, q and r being propositions, $q \sim p$ is the proposition equivalent to the proposition that r is implied by the product of $p \supset r$ and $q \supset r$. Such is the definition of the phrase, p or q. It is noteworthy that, whilst pq is true when and only when p and q are *both* true, the sum $p \sim q$ is true whenever *either* p or q is true. Among cardinal theorems I will, further, mention the laws of tautology, commutation, association and distribution:

$$pp (\text{or } p^2) = p, \qquad p \sim p = p ;$$

$$p \sim q = q \sim p, \qquad p \sim q = q \sim p ;$$

$$(p \sim q) \sim r = p \sim (q \sim r), \qquad (p \sim q) \sim r = p \sim (q \sim r);$$

$$p \sim (q \sim r) = (p \sim q) \sim (p \sim r),$$

$$p \sim (q \sim r) = (p \sim q) \sim (p \sim r) = p \sim q \sim p \sim r.$$

The *negative*, $-p$, of p is a proposition definable thus:

$$p \supset p . q \supset q . \supset : - p = . p \supset q,$$

which states that $-p$ is the proposition equivalent to the proposition that p implies all propositions; and we have the theorem of *double negatives*: $-(-p) = p$. Also the theorems of contradiction and excluded middle: $-p \sim q$ is false; $-p \sim q$ is true.

Definitions and Theorems in Class Logic. —As already pointed out, a propositional function—say, x is a pragmatist, or tan $x = y$—though a proposition in form, is not one in fact, being neither true nor false. But such a function yields a proposition whenever the indeterminate terms, as x, y, are replaced by determinate terms. Thus any such function is a sort of envelope of a limitless number of propositions. A function being given, those terms that on being substituted for its indeterminates yield true propositions are said to constitute a *class*. The symbolism $x \ni \phi(x)$ means "the class of terms x such that $\phi(x)$ is true," and primitive proposition (1) asserts that, if the individual k is a member of the class, $\phi(k)$ is true. Two functions $\phi(x)$ and $\Psi(x)$ are said to be *equivalent* when the propositions of every pair of propositions obtainable by substituting definite terms for x are equivalent; and (2) states that when two functions are equivalent the corresponding classes are the same—composed of the same individuals. If the propositions derivable from $\phi(x)$ are all of them false, the function is said to determine a *null-class;* and it readily follows that all null-classes are *extensionally* the same, so that we can, in this sense, speak of *the* null-class. The definition and symbolic expression of "x is identical with y," x and y being individuals, is $x = y . = : x \in u . \supset_u . y \in u$, where $\supset_u$ means "implies for every (class) u." The relation in question is *symmetric*, a fact involved in the theorem, $x = y . = . y = x$. A *singular* class u (class of but one term) is defined to be such that

$$x \in u . y \in u . \supset . x = y ;$$

and a singular class u is symbolically distinguished from its term a by writing $\imath a$ to denote u, and $\jmath u$ to denote a; so we have $\imath a = u$, $\jmath u = a$, and $\imath \jmath u = u$, but not $u = a$. The notion of *inclusion* of the terms of a class u by a class v is denoted by $u \supset v$ (where $\supset$ is the symbol for "implies" in propositional logic) and is defined to be

such that $u \supset v. = : x \epsilon u . \supset . x \epsilon v$. Two classes u and v are (extensionally) *identical*, and we write $u = v$, when and only when $u \supset v$ and $v \supset u$. Two classes are *disjoint* if neither includes a term of the other. It is necessary to avoid confounding ϵ with the use of $\supset$ in class logic, the former holds between an *individual* and a class but $\supset$ holds only between classes. Thus, if class $u \supset$ class v, and if individual $a \epsilon u$, we can not write $a \supset v$.

The important notions of class *multiplication* and *summation* are definable as follows. The logical *product* of the classes u and v, which is denoted by $u \frown v$, is such that $u \frown v = . x \ni (x \epsilon u . x \epsilon v)$; while the logical *sum*, $u \smile v$, u and v being disjoint or not, is such that $u \smile v. = . x \ni (x \epsilon u . \sim . x \epsilon v)$. Among cardinal theorems are the laws of *tautology, commutation, association, distribution* and *double negation:*

$$u \frown u = u = u \frown u ;$$

$$u \frown v = v \frown u, \quad u \smile v = v \smile u ;$$

$$u \frown (v \frown w) = (u \frown v) \frown w. \quad u \smile (v \smile w) = (u \smile v) \smile w ;$$

$$u \frown (v \smile w) = (u \frown v) \smile (u \frown w),$$

$$u \smile (v \frown w) = (u \smile v) \frown (u \smile w) ;$$

and $- (- u) = u$, where $- u$, called the negative of u, is, by definition, such that $- u. = . x \ni (x - \epsilon u)$.

The foregoing sketch indicates how the class logic sends its roots down into the soil of the propositional logic, and there is at the same time exhibited a remarkable parallelism between the two logics. It is important, however, to note the fact, pointed out by Schröder, that the parallelism is not thoroughgoing. For example, if p, q, r be propositions and a, b, c be classes, we have

$$pq \supset r. = : p \supset r . \smile . q \supset r,$$

but *not*

$$a \frown b \supset c. = : a \supset c . \smile . b \supset c.$$

Explanations, Definitions and Theorems in Relational Logic.—In its present form this calculus is mainly the creation of Mr. Bertrand Russell. It was he who perceived and demonstrated the advantage of adopting the extensional as distinguished from the intensional view of relations. It was he who perceived and demonstrated its preeminent importance in and for mathematics. Finally, it was he who cast its general principles—primitive propositions, fundamental definitions, theorems and their proofs—in symbolic form (cf. *Revue de Mathematiques*, vol. 7, 1900–1901).

In order to understand the doctrine including its primitive propositions above given, it will be necessary to explain or define the principal concepts involved in it and to associate with them the symbols (including those already explained) by which they are denoted. These concepts and symbols are as follows, the numbers (1), (2), ⋯ referring to primitive propositions. The writing xRy means to assert that x has the relation R to y, so that a relation has *sense* or direction; the symbols ρ and $\breve{\rho}$, called respectively the *domain* and the *codomain* of R, denote respectively the classes of terms that may stand before R and after R; the logical sum of these classes is the *field* of R; if x be a term of ρ, $\breve{\rho} x$ denotes the class of terms y such that xRy, and if x be a term of $\breve{\rho}$, ρx is the class of terms y such that yRx; a class is said to *exist* unless it be a null-class, and the *existence* of a class is affirmed by writing $\exists$ before its symbol, as in (3); if u is a class of terms of ρ, $\breve{\rho} u$ is the class of terms y such that, given any one of them, there is in u an x for which xRy; on the other hand, u again being a class of terms of ρ, $u \breve{\rho}$ denotes the class of terms y such that for *every* term x of u we have xRy; if, now, u is a class of terms in the codomain $\breve{\rho}$, ρu denotes the class of terms such that, given any one y of them, there is in u a term x for which yRx, while, on

the other hand, u_ρ is the class of terms such that, given any one y of them, we have, for *every* x of u, yRx; R is said to be *included in* R', $R \supset R'$, if and only if, for all x's and y's, xRy implies $xR'y$; and R and R' are *equivalent* when and only when each of them includes the other; (2) asserts that, given any R, there is a relation R'—called the converse of R and denoted by $\breve{R}$—such that xRy and $yR'x$ are equivalent functions; a relation R is said to be *symmetric* when and only when $R = \breve{R}$; (3) affirms that, given any two terms x and y, there is between them a relation that does not subsist between the terms of any other pair of terms; the logical *sum*, $R_1 \smile R_2$, of two relations R_1 and R_2 is a relation such that the proposition $x(R_1 \smile R_2)$ is equivalent for all x's and y's to the logical sum of the propositions xR_1y, xR_2y; the logical product, $R_1 \cdot R_2$, is such that $x(R_1 \frown R_2)y$ is equivalent to the product $xR_1y.xR_2y$, for all x's and y's; if K be a class of relations, their *sum*, $\smile' K$, affirmed by (4) to be a relation, is a class of relations such that, given any one R of them and any pair x, y for which xRy, there is in K a relation R' for which $xR'y$, and that, given any R' of K and a pair x, y for which $xR'y$, there is in the sum-class an R for which xRy; similarly the *product*, $\frown' K$ assumed by (5) to be a relation, is the class of relations such that, R being any one of them and x and y being a pair for which xRy, then, for *every* R' of K, $xR'y$, and conversely, if x and y be a pair for which $xR'y$ holds for every R' of K, there is in the product-class an R for which xRy; R_1 and R_2 being relations, their *relative product*, R_1R_2, affirmed by (6) to be a relation, is defined to be such that, if xR_1R_2z, there is a y for which xR_1y and yR_2z, and that, if xR_1y and yR_2z, then xR_1R_2z; R^2 means RR; a relation R is transitive if and only if R^2 is included in R, that is, if the product of xRy and yRz implies xRz; R being a relation, its *negative*, $-R$, affirmed by (7) to be a relation, is defined to be such that, $x - Ry$ is true or false according as xRy is false or true; if y is a class of classes, their *sum* $'y$ is the class of terms x such that $x\epsilon^2 y$; *diversity*, $0'$, is defined to be the negative of identity, so that $0' = -1'$; R is a *uniform* relation, $Nc \dashv 1$, when and only when, whatever x of ρ be given, there is one and but one y for which xRy; R is a *couniform* relation, $1 \dashv Nc$, when $\breve{R}$ is uniform; R is a *biuniform* relation, $1 \dashv 1$, when it is both uniform and couniform.

Such are the chief of the concepts in the superstructure of the logic of relations. In the study of relations one is close to reality. We do not say with Hegel "Das Seyn ist das Nichts" but rather with Lotze "Being consists in relations." The realm of the thinkable is filled by a multidimensional tissue of relations. These are finer than gossamer but stronger than cables of steel. Among the *theorems* of the general theory the following, which are readily proved by means of the symbolic machinery, are cardinal. Each relation R has one and but one converse relation $\breve{R}$; the converse of the converse of a relation is equivalent to the relation, that is, $\breve{\breve{R}} = R$; if $R_1 = \breve{R}_2$, then $\breve{\rho}_1 = \rho_2$, and $\rho_1 = \breve{\rho}_2$, and, if the latter two equivalences subsist, then $R_1 = R_2$; also, if $R_1 = \breve{R}_2$, then $\breve{R}_1 = R_2$; the converse of the relative product of two relations is equivalent to the relative product of their converses reversed in order, that is $(\breve{R_1R_2}) = \breve{R}_2\breve{R}_1$; if R is transitive and if xRz, there exists a y such that xRy and yRz; the converse of the negative of a relation is equivalent to the negative of the converse of the relation; a null-class is included in every other class; if, for every x in the domain ρ of

R, xRy is equivalent to $y \epsilon x$, then $R = \breve{\epsilon}$; if u and v are existent (not null) classes, there exists a relation subsisting between every term of u and every term of v but not between other two terms; if u is an existent class, there exists a relation R such that xRu implies for every x both $\rho = u$ and $x \epsilon u$, and, conversely, the product of $\rho = u$ and $x \epsilon u$ implies xRu for every x; identity is transitive; identity is equivalent to its converse; the relative product of identity by itself is equivalent to identity; diversity is equivalent to the converse of diversity; if $R_1 \breve{R}_2$ is included in diversity, so is $\breve{R}_1 R_2$, and conversely; identity is biuniform; if a relation is biuniform, so is its converse; if a relation is couniform, the relative product of it and its converse is included in but is not always identical with identity; if two relations are biuniform, so is their relative product; given that R_1 and R_2 are uniform relations, that u is a class included in ρ_1, that $\breve{\rho} u$ is included in ρ_2 and that $R_1 R_2 = R$, then the two classes, $\breve{\rho}_2(\rho_1 u)$ and $\breve{\rho} u$, are equivalent; if R_1 is uniform and if $R_2 = R_1 \breve{R}_1$, then R_2 is transitive and symmetric; conversely, *if an existent relation R_2 is transitive and symmetric, then there exists a uniform relation R_1 such that $R_2 = R_1 \breve{R}_1$.*

So striking as well as important is the theorem last stated that I can not refrain from presenting its demonstration, which runs as follows: R_2 being given, ρ_2 is also given: let x be a term of ρ_2, and denote by u the class $\breve{\rho}_2 x$; let R_1 be such that $xR_1 u$ means $x \epsilon \breve{\rho}_2$ and $u = \breve{\rho}_2 x$; then, if $yR_1 u$, $y \epsilon \rho_2$ and $u = \breve{\rho}_2 y = \breve{\rho}_2 x$; but, if $xR_1 u$ and $yR_1 u$, then, $xR_1 \breve{R}_2 y$; and, as R_2 is transitive and symmetric, $xR_2 y$; hence, as $xR_1 \breve{R}_1 y$ implies $xR_2 y$, $R_1 \breve{R}_1$ is included in R_2; again, as R_2 is transitive and symmetric, if $xR_2 y$ then $x \epsilon \breve{\rho} x$, and so $xR_2 y$ implies $xR_1 \breve{\rho} x$ and $yR_1 \breve{\rho} x$, and hence implies $xR_1 \breve{R}_1 y$; hence R_2 is included in $R_1 \breve{R}_1$; hence $R_2 = R_1 \breve{R}_1$; moreover, R_1 is uniform, its codomain consisting of the single term u. Hence the theorem.

As in the case of propositions and in that of classes, so here, too, are valid the theorems of tautology, association, commutation, distribution and double negation:

$$R \frown R = R = R \frown R;$$

$$(R_1 \frown R_2) \frown R_3 = R_1 \frown (R_2 \frown R_3),$$

$$(R_1 \smile R_2) \smile R_3 = R_1 \smile (R_2 \smile R_3);$$

$$R_1 \frown R_2 = R_2 \frown R_1, \quad R_1 \smile R_2 = R_2 \smile R_1;$$

$$R_1 \frown (R_2 \smile R_3) = (R_1 \frown R_2) \smile (R_1 \frown R_3),$$

$$R_1 \smile (R_2 \frown R_3) = (R_1 \smile R_2) \frown (R_1 \smile R_3);$$

$$-(-R) = R.$$

Awhile ago I promised to "explicate" the thesis of modern logistic, to state it, that is, explicitly in terms of the logical primitives upon which as the sufficient foundation it asserts that the entire body of mathematics, both actual and potential, stands as a superstructure. The primitives in question have been given; so that, except for a restatement of the thesis in terms of them—which I shall omit as being now easy and involving useless repetition—I may claim to have done much more than fulfil the promise; for I have given in addition to the primitives, which were all that was essential, a digest of modern logic. Indeed, the concepts above defined and the theorems above stated, though they are conventionally assigned to logic, are evidently, if the thesis be true, genuine parts of mathematics.

How is the thesis, if true, to be established? Obviously not, in the ordinary sense, as the conclusion of a syllogism. No, it affirms that a certain thing can be done, namely, that all definable mathematical ideas and all mathematical theorems are respectively definable and demonstrable in terms of the primitives given. The only way to show that the deed is

performable is to perfrom it. Here nothing can succeed except success. Happily the procedure in question need not be applied to *all* mathematical concepts and theorems but only to those—and they are not so numerous—upon which, it is admitted, the remainder rest. Well, an examination of the volumes of the *Revista di Matematica* and of its continuation, the *Revue de Mathematiques,* will show that the principal mathematical branches have been successfully subjected to the treatment in question, with reference, however, to primitive-systems differing somewhat from that above given. As for the latter system, its adequacy to the demands of the thesis has been shown by Russell in his "Principles" with approximate completeness and with as much rigor as discourse, mainly non-symbolic, can be reasonably expected to attain. If, as is to be expected, new branches of mathematics shall arise in the days to come, though we can not be absolutely certain, we may confidently expect that they will be congruous with existing doctrines and will not demand a radical change in foundations.

Process of Testing the Thesis Illustrated.—The little time that remains to me for this address, I shall devote to illustrating by means of a few cardinal examples, the procedure by which the thesis is justified. And I shall begin with the concept of *cardinal number.* Before defining *cardinal number of a class,* we define what is meant by *sameness* of cardinal number, or, better, what is meant by saying this class and that have the same cardinal number. Two classes a and b are said to have the same cardinal number when there is a biuniform relation, or, as we commonly phrase it, a one-one correlation between them. A slight change in the statement is necessary to prove suitable for zero. Then the cardinal number of a class a is defined to be *the class* whose terms are the classes having each of them, according to the preceding definition, the same cardinal number as a. Thus with each class is associated a definite cardinal number. That of the null-class is named *zero* and denoted by 0; that of a singular class is called *one* and denoted by 1. Addition of cardinals is definable in terms of logical addition of classes: if a and b be two disjoint classes having respectively the numbers α and β, the sum $\alpha + \beta$ is the number of the logical sum (a class) $a + b$ of a and b. If a and b are singular classes, the cardinal of their sum may be named *two* and denoted by the symbol *2,* in which case $1 + 1 = 2$; and so on. *Multiplication* of cardinals is also defined in purely logical terms. This is done by means of the concept (due to Whitehead) of *multiplicative* class, which is itself given in terms of logical constants: k being a class of disjoint classes, the *multiplicative class* of k is the class of all the classes each of which contains one and but one term of each class in k. Then the *product* of the cardinal numbers of the classes in k is defined to be the cardinal number of the multiplicative class of k. As multiplication and addition in class logic are commutative, associative and distributive, it readily follows that these laws are valid for cardinal numbers. In the manner indicated the entire theory of cardinals can be established. And thus it appears—to refer again to an example before cited—that the foundation assumed by Weierstrass for the theory of the real variable is itself underlaid by a basis in pure logic.

It is noteworthy that the foregoing concept of cardinal is independent of the (as yet undefined) notion called *order* and that it equally comprises both *finite* and *infinite* cardinals, the distinction of finite and infinite being this: the cardinal number of a class a is infinite or finite according as a is or is not such that there is a class b com-

posed of some but not all of the terms of a and having to a a biuniform relation. In respect to the finite cardinals, they may be defined as follows, presenting them in what, once order is defined, will be called a *series*, 0, 1, 2, . . . Let zero (0) be defined as above; let the *cardinal next after the cardinal* n be defined to be the cardinal $n+1$; let N, the class of finite cardinals, be defined to be the class of cardinals that are contained in every class that contains 0 and contains $n+1$ if it contains n. It remains then to show that the two definitions of finite cardinals are equivalent, and that can be done.

Cardinals, we have seen, are *classes*. The ordinary rational numbers, or fractions, are not classes, but are, as we shall see, *relations* of finite cardinals. Let a be any given finite cardinal, and let x and y be any finite cardinals such that $xa = y$. Denote by A the relation such that xAy is equivalent to $xa = y$. Similarly, to any finite cardinal n there corresponds a relation N whose domain and codomain are respectively composed of all the finite cardinals x and y such that $xn = y$. If $ab = p$ and $cd = p$, that is, if $ab = cd$, then aBp and cDp, whence $p\breve{D}c$, so that $aB\breve{D}c$. The relation $B\breve{D}$, the relative product of B and the converse of D, is named rational number, or fraction, and denoted by b/d. If $ab = cd$, it readily follows that $b/d = a/c$. The rational $n/1$ is commonly denoted by n, but the rational n and the cardinal n are radically different, the former being a relation while the latter is a class.

The cardinals and rationals are signless. Like the rationals, positive and negative integers and fractions are relations but they are relations of a different type. Suppose the finite cardinals arranged as by their second definition above given. Let R be such that xRy, x and y being finite cardinals, means that, in the mentioned arrangement, y is the immediate successor of x; then $x\breve{R}y$ means that y is the immediate predecessor of x. It is readily proved that R^p is the converse of $(\breve{R})^p$ or, what is the same, of $\breve{R}^p$. The relations R^p and $\breve{R}^p$ (p being a finite cardinal) are defined to be the positive and negative integers familiarly denoted by $+p$ and $-p$ respectively. Thus to each finite cardinal p there corresponds a positive integer, $+p$, and a negative integer, $-p$. If x, y and p are finite cardinals, the propositions, xR^py and $x+p=y$, are equivalent; so, too, are $x\breve{R}^py$ and $y+p=x$ or $x-p=y$. Similarly if x be a rational number, and if y and z stand for any two rational numbers so related that $y+x=z$, the relation in question is denoted by $+x$; but if y and z are so related that $y-x=z$, the relation is denoted by $-x$.

Before speaking of the *ordinal number*, it is necessary to tell what is meant by saying of a class that it is ordered or that its terms are arranged in a *series*. This, which is one of Russell's most brilliant achievements, was accomplished as follows. I here but indicate the method and state the result. The method was precisely that of research in natural science, namely, he collected together the various kinds of relation by which what is called order, whatever order in its essence should turn out to be, is generated. These relations, which he found to belong to one or another of six distinct types, turned out, upon penetrating analysis, to be reducible to a single type, namely, that of relations at once *transitive* and *asymmetric*, an asymmetric relation R being such that, if xRy, then not yRx. The conclusion may be stated to be that, a class being given, if there exist a transitive asymmetric relation R such that, x and y being any two whatever of its terms, either xRy or else yRx, the class is

thus arranged in a *series;* and that order otherwise generable is generable by such a relation. The result is of course subject to such doubt as must always attend the method employed, but its correctness seems highly probable. It can be easily proved that, given any three terms x, y, z of an open series, we have xRy and yRz, or yRz and zRx or zRx and xRy, that is, one of the three terms is *between* the other two; and if the series be closed, like that of the points of a circle, it can be rendered open by *cutting* it—that is, by regarding it as beginning (or ending) with some (any) definite term.

We are now prepared to present the notion of ordinal number. If, given two series s_1 and s_2, there subsist between them, regarded as classes, a biuniform relation R such that, a_1 and b_1 being any two terms of s_1 and a_2 and b_2 their respective correspondents (through R) in S_2, a_1 precedes or follows b_1 according as a_2 precedes or follows b_2, then the series s_1 and s_2 are said to be *like.* Plainly likeness is a transitive and symmetric relation. Two like series are said to have the *same ordinal number* or the *same order-type.* Herewith ordinal number, or order-type, of a series is yet not defined. The definition is: the ordinal number, or order-type, of a series s is the *class* of all series like it. Or, defining *like* relations to be such as generate like series, we can define ordinal number, or order-type, of a series-generating relation to be the class (a relation by primitive proposition) of series like it. The definition does not distinguish finite and infinite and so applies to both. In case the terms of a series constitute a finite class, the cardinal number of the class and the ordinal number of the series obey the same laws and are commonly denoted by the same name and symbol. Yet they are radically different notions. For example, the *cardinal three* includes the class composed of a, b and c, but not the series a, b and c as such, while the *ordinal three* includes the series but not the class. On transition to infinites the distinction is forced upon us, for infinite cardinals obey, for example, the law of commutation, while the infinite ordinals do not.

I have time for but a single indication pointing the way to the concept and theory of *real* numbers. Consider, for example, the two familiar classes: A, the class of rationals less than 2; B, the class of rationals whose squares are less than 2. Each of these classes possesses the properties: (1) it does not contain all the rational numbers; (2) it contains all the rational numbers less than any one of its numbers; (3) every number in it is less than some other number in it. Any class of rationals that has the three properties is named *segment* (of rationals). Given a segment s, the class of rationals not belonging to s may be called the *cosegment* of s. It is found that the class of all segments admits of a theory precisely isomorphic with that of the real numbers as usually defined. Hence the segments are named *real numbers.* Segments fall into two classes according as their cosegments have or have not a smallest rational. In the former case the segment is called a *rational* real number. Thus segment A is the rational real *two* or 2. In the other case, the segment is called an *irrational* real number. Thus segment B is the irrational real commonly denoted by $\sqrt{2}$. It is obvious that segments and reals might just as well be defined by the relation greater than instead of less than. The decisive advantage of the foregoing definition, which makes no appeal to the (as yet) undefined notion of *limit,* is that it avoids the necessity of *assuming* a limit where there is none, as in case of class B.

It is to be noted that in usage various kinds of numbers are denoted by the same symbol. This is due to the fact that custom antedates criticism. Thus 2 stands for a cardinal (a class), for a positive integer (a relation), for a rational number or fraction (a relation), for an ordinal (a relation), and for a rational real (a class)—neither the classes nor the relations being of the same kind.

Passing now to the notion of the (linear) *continuum*, it is to be defined in ordinal terms and without the logically vicious assumption often tacitly made that the continuum to be defined is already immersed in a continuum. The following procedure is due to G. Cantor. Let η denote the order-type of series *like* that of the rationals taken in so-called natural order. Any series of this type has the following properties, all of them ordinal: (1) it is denumerable; (2) it has neither beginning nor end; (3) it is compact. A series of terms in a series of type η is said to be *fundamental* if it is a *progression*, that is, if it is like the series 1, 2, 3, $\cdots$; and it is described as *ascending* or *descending* according as its terms follow one another in the same sense (or direction) as do those of the series η or in the reverse sense. A term of a series is a *limit* if it immediately follows (or precedes) a class of terms of the series and does not immediately follow (or precede) any one assignable term of it. It follows that a fundamental series s of a series η has a limit if in η there is a term that is first after or first before all the terms of s according as s is ascending or descending. A series is said to be *perfect* if (1) all its fundamental series have limits and (2) all its terms are limits of fundamental series. It can be proved that a series whose terms are terms of a perfect series and which, besides being denumerable, are so distributed that there is one between every two terms of the perfect series, is a series of type η. We can now define: a series θ is *continuous* if it is perfect and contains a denumerable class of terms such that there is one of them between every two terms of θ. The definition is based upon the properties found to characterize the series of real numbers from 0 inclusive to 1 inclusive.

The significance of what has been said is by no means confined to analysis. Yet I wish, in closing, to refer explicitly to geometry. As a branch of mathematics, geometry does not claim to be an accurate or true description of actual or perceptual space, whatever that may be. As for the notion and the name of space, it does not seem to be a *modern* discovery that they are not essential to geometry, for, as Peano has pointed out, neither the one nor the other is to be found in the works either of Euclid or of Archimedes. What, then, is geometry? And how related to the thesis of modern logistic? The answer must be in terms of *form* and *subject-matter*. As to form, geometry is, as Pieri has said and by his great memoirs has done as much as any one to show, a purely "hypothetico-deductive" science. It is true indeed that in each of the postulate-systems—whether those of Pieri or of Pasch or of Peano or of Hilbert or of Veblen or of others—that have recently been offered as basis for descriptive or projective or metric geometry or for any sub-division of those grand divisions, there occurs at least one postulate in categoric form, as, for example, "there exists at least one point"—thus seeming to assert or to imply that the geometry in question, whatever variety it may be, transcends the hypothetic character and has in fact validity of an extra-theoretic or external kind. Nevertheless, the seeming is appearance only. What the geometrician really asserts, and he asserts nothing

else, is that, *if* there be terms, which he calls points, and might as well call "roints" or "raths" or "momes" or any other name (what's in a name?), that satisfy the given postulates, then they satisfy certain propositions called theorems. The only existence asserted by or in geometry is thus the existence of certain *implications*. As to subject-matter, that of geometry, as Russell has, I think, shown beyond a reasonable doubt, is multiple series or, more radically, the relations by which such series are generated or in which they extensionally consist.

I wish to add in closing that this address had not been possible but for the far-reaching researches and brilliant expositions of Schröder, Russell and Couturat in the works already cited.

C. J. KEYSER
COLUMBIA UNIVERSITY

CHEMISTRY AT HARVARD UNIVERSITY

THE following letter has been prepared by the committee of overseers to visit the chemical laboratory of Harvard University and by several others who are especially interested in the subject:

HARVARD UNIVERSITY is in urgent need of the endowment of modern facilities for chemical instruction and research.

Some progress toward such an endowment has already been made by the conditional offer of contributions for the construction of a special laboratory for research in physical and inorganic chemistry, as a memorial to Wolcott Gibbs.

Wolcott Gibbs was a pioneer in scientific research in the field of inorganic and physical chemistry, and for many years was considered the foremost chemist of America. He died on December 9, 1908, in his eighty-seventh year. The greater part of his useful life was spent as Rumford professor at Harvard University, and it is eminently fitting that any memorial to this great and good man should take a form which would further that branch of chemistry to which he had devoted his splendid abilities.

This project forms a highly suitable beginning of the much-needed endowment of modern facilities for chemical instruction and research at Harvard University, because in precise investigations of this kind Harvard is among the leading institutions of the world. Such work demands, for its highest development, construction and facilities superior to any now in existence; and above all this laboratory should be designed for research only, and separated from the rooms in which elementary teaching is conducted. The new building would also partially relieve the very disadvantageous and unhygienic condition of Boylston Hall, now one of the most crying evils in Harvard University.

This Wolcott Gibbs Memorial Laboratory would form part of the group of several buildings necessary for the adequate accommodation of the department of chemistry. The report of the Committee of Overseers to Visit the Chemical Laboratory contains a provisional plan of this projected group, which offers a magnificent opportunity for other large gifts. These would form dignified memorials of benefactors or those named by them, as well as permanent sources of usefulness to Harvard and to America.

The report just mentioned calls attention to the important rôle played by pure chemistry in almost all departments of industrial science which contribute towards the health and prosperity of mankind, and concludes:

"The last century has been a century of power, by the perfection of machinery and the development of electricity. The coming century promises to be a chemical century. Should Harvard, if all this be true, be content until it has obtained the best chemical laboratory in the world?"

Towards the erection of the Wolcott Gibbs Memorial Laboratory subscriptions of nearly $53,000 have already been made, most of them upon the condition that $47,000 more be immediately secured. Checks either for this fund or as contributions toward one of the other laboratory buildings may be drawn to the order of Charles Francis Adams, 2d, treasurer of Harvard College, 50 State Street, Boston.

J. COLLINS WARREN, CHARLES W. ELIOT,
JAMES M. CRAFTS, ALEXANDER AGASSIZ,
ELIHU THOMSON, HENRY P. WALCOTT,
E. D. PEARCE, HENRY L. HIGGINSON,
CLIFFORD RICHARDSON, ALEXANDER COCHRANE,
CHARLES H. W. FOSTER, FREDERICK P. FISH,
MORRIS LOEB, HARRISON S. MORRIS,
A. LAWRENCE LOWELL, E. MALLINCKRODT, JR.,

Committee of the Overseers to Visit the Chemical Laboratory

President Lowell's interest is emphatically expressed in the following letter, which he kindly permits to be published:

November 24, 1909.

Dear Mr. Sanger:—

I hope most earnestly that you will be successful in your efforts to raise money for a new chemical laboratory. That Boylston Hall has been inadequate for purposes both of research and instruction has long been lamentably evident, and that Harvard University should not be properly equipped in this field is the more to be regretted, in view of the rapidly increasing importance of chemistry in industry and medicine. It is well known that the industries of America are behind those of Germany in the use of chemical processes, and better chemical facilities at our universities would help greatly towards curing this defect. It seems unfortunate that the magnificent research in chemistry being conducted at Harvard should be hampered by the lack of laboratory room. Yours very truly,

A. Lawrence Lowell

Professor C. R. Sanger.

SCIENTIFIC NOTES AND NEWS

In the present issue of Science are printed the address of the retiring president of the American Association for the Advancement of Science, Dr. T. C. Chamberlin, of the University of Chicago, and of the vice-president of the section for mathematics and astronomy, Professor C. J. Keyser, of Columbia University. In the issue for next week will be printed the proceedings of the Boston meeting, which promises to be of more than usual interest and importance.

The Chicago Geographical Society has awarded the Helen Culver gold medal to Commander Robert E. Peary, for distinguished services in exploration, and to Professor Thomas C. Chamberlin, of the University of Chicago, for distinguished services in geographical research. The medals will be presented at the annual dinner of the society on January 26.

The Paris Academy of Sciences has awarded medals for aeronautic achievements as follows: gold—Wilbur and Orville Wright, Blériot, Farman, Count de Lambert, Santos-Dumont, De La Vauix, Voisin and Count Zeppelin; enamel—Bremuet, Paulhan, Delagrange, Rougier and Esnault Pelterie.

As has been everywhere announced, the University of Copenhagen has reported adversely on the claims of Dr. Frederick A. Cook to have reached the North Pole. This report will not now come as a surprise to any one nor had a different result been anticipated at any time by those conversant with the circumstances, as is indicated by the note published in this journal, on September 10, when the announcement was first made.

Dr. Theo. Gill, of the Smithsonian Institution, and Professor August Brauer, director of the Zoological Museum, Berlin, have been elected foreign members of the Zoological Society of London. The following corresponding members were elected: Mr. E. Salis-Schwabe, of Manaos, Brazil; Professor W. Kukenthal, of Breslau, Germany; Professor Gustave Gilson, of Ostend, Belgium, and Dr. E. G. Racovitza, sub-director of the Laboratoire Arago, Banyuls-sur-Mer, France.

Dr. Ephraim Miller, professor of mathematics and astronomy in the University of Kansas, who will celebrate his seventy-seventh birthday on April 25, will retire from active service at the close of the academic year under the provisions of the Carnegie Foundation.

Professor J. Culver Hartzell, B.S. (Chattanooga), M.S. (Yale), Ph.D. (Munich), has resigned as head of the department of geology and chemistry in the University of the Pacific, the resignation to take effect at the close of the present academic year.

Dr. E. B. Tylor, professor of anthropology at Oxford University, will retire from active service.

Dr. Leo Loeb, assistant professor of pathology at the University of Pennsylvania, will at the close of the present academic year become director of an institution for the study of cancer in St. Louis.

Dr. Shepherd Ivory Franz, psychologist at the Government Hospital for the Insane, Washington, D. C., has been appointed scientific director of that institution.

Mr. W. M. Tattersall has been appointed keeper of the Manchester Museum in succession to Dr. W. E. Hoyle.

DR. G. GÜRICH, docent for geology at Breslau, has been appointed director of the Geological Institute at Hamburg, to succeed the late Professor Gottsche.

PROFESSOR A. CRUM BROWN, F.R.S., has been elected president of the Scottish Meteorological Society.

WE learn from the London *Times* that Professor Kocher, of Berne, who was recently awarded the Nobel prize for medicine, has announced his intention of dividing the prize into two amounts, one of which he will present to the Red Cross Hospital at Berne. The remaining sum will be used for the benefit of the poorer class of medical students at Berne.

THE prize of the Berlin Astronomical Society for the best calculations of the path of Halley's comet has been awarded to Messrs. Cole and Crommelin.

DURING the past two years Mr. John D. Haseman has been collecting fishes for the Carnegie Museum in South America. His last journey was from Corumba in the valley of the La Plata to Manaos in Brazil. No message having been received from him for seven months, fears for his safety began to be entertained, but they were relieved a few days ago by a message from Manaos, saying "I have come out to civilization, tired and worn out, but still able to catch fish." He has added many thousands of specimens to the collections of the museum.

THE board of regents of the University of Minnesota has allowed Professor F. L. Washburn, of the entomological division of the experiment station, two months' vacation, during February and March of the present year. This time will be spent, as far as possible, in the study of conditions governing the control of insects affecting market gardens and small land ownings in Europe.

DR. ROBERT BENNETT BEAN, associate professor of anatomy in the Philippine Medical School, will return to America, reaching Baltimore in February.

PROFESSOR HAL DOWNEY, of the department of animal biology of the University of Minnesota, will next year have sabbatical leave of absence to study abroad.

FROM the members of the American committee appointed by Commissioner Brown for the third International Congress for Home Education to be held in Brussels next summer, the name was omitted of Dr. D. P. McMillin, director of child study and pedagogical investigation in the Chicago public schools. He is chairman of the sub-committee on child study.

DR. AUGUSTO RIGHI, professor of physics at Bologna, will next year give a course of lectures at Columbia University.

MR. MARCONI, who received a Nobel prize for physics, lectured in Stockholm on December 11, in accordance with the usual custom, upon radiotelegraphy, before a large body of well-known men of science.

ACCORDING to *Nature*, on November 24, exactly fifty years after the publication of the "Origin of Species," a number of biological and medical societies of the Netherlands met in one of the large halls of the Amsterdam Zoological Gardens (Natura Artis Magistra) to commemorate this event and the influence which Darwinism has continued to exercise on human thought since then. Addresses were delivered by Professor Hugo de Vries on Darwin's visit to the Galapagos Archipelago, and by Professor A. A. W. Hubrecht on Darwin and the descent of man. A bust of Darwin occupied the center of the hall in front of the platform.

THE Pasteur Institute of Paris has presented to the Rockefeller Institute for Medical Research, of New York, a replica of the bronze bust of Louis Pasteur by Paul Dubois, in recognition of assistance rendered during the recent epidemic of cerebrospinal meningitis which prevailed in France.

A MONUMENT will be erected in Hilden, Germany, to Guilelmus Fabricius, the eminent surgeon. It is proposed to unveil a statue of Fabricius on the three hundred and fiftieth anniversary of his birth, June 25, 1560.

WE are requested by Frau Marie Dohrn to state that in looking through the late Professor Anton Dohrn's papers and manuscripts, much has been found relating to the origin

and growth of the Naples Zoological Station that he founded. Whether from these materials it will be possible to reconstruct a complete history of the station, can not as yet be definitely said; but at all events the many letters that Dohrn wrote to his scientific friends could not fail to fill up many gaps and throw more light on the whole subject. All those, accordingly, who have in their possession any letters from Dohrn, and are willing to give a helping hand in this undertaking, would be doing a great service if they would lend these letters, or copies of them, for the purposes of the work. All communications should be addressed to Frau Marie Dohrn, Rione Amedio, 92, Naples.

Dr. Charles B. Dudley, chief chemist of the Pennsylvania Railroad Company, past president of the American Chemical Society, died at his home in Altoona, Pa., on December 21 at the age of sixty-eight years.

Dr. Ludwig Mond, the distinguished industrial chemist and investigator, a founder of the alkali firm of Brunner, Mond and Co., died in London on December 11, at the age of seventy years.

The U. S. Civil Service Commission will hold an examination on January 12 for the appointment in the Bureau of Standards of an engineer-physicist at $3,000 per year and associate engineer-physicist at $2,000 per year. Applicants should be able to carry on independent research in the field of engineering physics, and should have training and experience in the inspection and testing of engineering and structural materials, the operation of testing machines and the interpretation of the results of investigations. Titles and references to the original source of publication of all papers published should be given.

According to the London *Times*, it is planned to establish in Germany a Chemische Reichsanstalt to undertake for chemical industry similar functions to those which the Imperial Physical Institute performs for engineering. The undertaking is being subsidized by the state, and it is expected that the annual maintenance will cost about £10,000.

A conference on the eradication of the hookworm disease will be held in Atlanta, on January 18 and 19. Delegates will be appointed to the conference from Alabama, Mississippi, South Carolina, Georgia and Florida.

The second general meeting of the International Institute of Agriculture was held at Rome beginning on December 12.

The annual exhibition of physical apparatus organized by the London Physical Society was held on December 14 at the Imperial College of Science, South Kensington.

The annual meeting of the Association of American Universities will be held at the University of Wisconsin on January 4–5. Among the subjects to be discussed at this meeting are "The Problem of the Assistant Professor," to be discussed by a representative of Leland Stanford University; "University Extension," to be presented by Director L. E. Reber, of the extension division of the University of Wisconsin; and "The Position and Importance of the Arts Course as Distinct from the Professional Course," to be read by President Woodrow Wilson, of Princeton.

UNIVERSITY AND EDUCATIONAL NEWS

At a meeting of the senate of the University of London on December 16, a letter was read from Mr. Otto Beit, announcing a large gift in the interest of medical research. Mr. Beit's brother, the late Mr. Alfred Beit, left £50,000 to found an "Institute of Medical Sciences." As the formation of this institute has for various reasons become impossible, Mr. Beit has decided to increase the sum left by his brother to £215,000. This fund, which is to be named "The Beit Memorial Fellowships for Medical Research," is to be devoted to the furthering of medical research work in all its branches. With this object a sum of £250 a year for three years is to be granted "to any man or woman of European descent, graduate of any approved university within the British Empire, who is elected to a Fellowship." The first election of fellows will take place on or before March 1, 1910.

THE Experiment Station *Record* states that the legislature has increased the rate of taxation for the support of the University of California from two to three cents for each one hundred dollars of assessed valuation. This is expected to provide an income for the current year of about $600,000. Appropriations were also made aggregating $130,000 for additional buildings and equipment at the University Farm at Davis, and $88,500 for its maintenance during the ensuing biennium; $20,000 for farmers' institutes; $15,000 for viticultural investigations; $12,000 for cereal investigations, and about $40,000 for the equipment and maintenance of the Southern California Pathological Laboratory.

MRS. PHŒBE HEARST has undertaken to build an anthropological museum for the University of California to cost about $500,000.

TULANE UNIVERSITY will receive $100,000 by will of Isidore Newman, of New Orleans.

THE old block of six tenements at the north end of the Sheffield Scientific School grounds, held for many years at a prohibitory price, has been bought for less than $35,000. It will now be torn down and the chemical laboratory extended over part of the site.

IN order to secure closer cooperation between the regents and the faculties of the University of Minnesota, the board of regents has passed the following resolution:

> *Resolved*, that the several deans of the university be requested to report to the board of regents at their next meeting some plan by which matters concerning the general interests of the university may be taken up and considered by some representative body of those directing the work of the university and the board of regents in closer relation than heretofore.

THE establishment of an agricultural college at Mayaguez, Porto Rico, has been authorized by the territorial legislature. I. W. Hart, of the School of Agriculture, São Paulo, Brazil, has been elected president.

MR. F. A. WOODS, chief of the Bureau of Plant Industry of the U. S. Department of Agriculture, has been elected dean of the agricultural department of the University of Minnesota.

DISCUSSION AND CORRESPONDENCE

"OFFICIAL" LIST OF ZOOLOGICAL NAMES—AN OPEN LETTER TO PROFESSIONAL ZOOLOGISTS

A NUMBER of zoologists have expressed the opinion that a list of the most common zoological names should be prepared and that the International Congress of Zoology should accept this list in the future as free from any operation of the law of priority. Other zoologists view this proposition as theoretically and practically open to very serious objections. In the hope of meeting the wishes of the representatives of both sides of this question I take the liberty of proposing an alternative plan, namely, that a list be made of the most commonly used zoological names, that these names be subjected to rigid study under the present international code, and that the international congress adopt this list as "official," with the provision that no change in any of the names in the list be accepted unless the reason for such change is first submitted to the International Commission on Zoological Nomenclature for careful study and unless said commission decides that the change is justified and necessary.

If the zoologists of the world will cooperate with me in this matter, I will endeavor to report to the International Commission at the Gratz meeting in 1910 a list of the kind proposed. It does not seem advisable to make this official list too large at first, but if the plan is found to be feasible, additional names could be placed on the list year after year, and eventually we would have a catalogue of all of the most common and most important names in zoology.

I invite the zoologists of the world to cooperate with me in this experiment on the following plan: Let any person interested in zoology send to me within the next three months a list of 100 zoological names which he considers the most important, and the most generally used. Let every man who is familiar with nomenclatural usages work out the status, under the international code, of 10 of the 100 names which he submits, giving the

exact spelling, the author, and the date and place of publication, with the statement that he considers the 10 names in question as the correct names of the animals involved.

I will agree to compile all the names sent in, to tabulate the votes on the different names (in respect to their importance and frequency), and if possible to verify the references and the nomenclatural status of the names in question. I will further agree to submit a list of say 100 to 300 such names to the International Commission on Nomenclature and to recommend that the commission report upon the list to the international congress.

All communications on this subject should be addressed to me as follows:

Dr. Ch. Wardell Stiles, secretary, International Commission on Zoological Nomenclature, Hygienic Laboratory, 25th and E Streets, Washington, D. C.

Ch. Wardell Stiles

GLACIAL CLAYS OF THE MAINE COAST

For a number of years these clays have been greatly neglected by geologists and zoologists. Mr. Frederick G. Clapp, in his recent paper,[1] has summarized and added to the work on this region.

Mr. Clapp gives a list of the Pleistocene fossils found in the clays. To this list should be added the following species of ophiuroids, which I found in August, 1909: two specimens of *Ophiura sarsii* Ltk., and one of *Ophiura nodosa* Ltk. These three specimens were found in close proximity in clay about 110 feet above sea level, by aneroid, and the location was at the Rockland Lime Company's deepest quarry, about two miles west of Crockett Point, in Rockland Harbor. This horizon is in the "Upper Clay" of Mr. Clapp's provisional division of these clays. I am indebted to Dr. Hubert L. Clark, for the determination of the species.

Robert W. Sayles

Harvard University

[1] "Complexity of the Glacial Period in Northeastern New England," *Bulletin of the Geological Society of America*, Vol. 18, pp. 505–556, 1908.

SCIENTIFIC BOOKS

The Natural History of Igneous Rocks. By Alfred Harker, M.A., F.R.S., Lecturer in Petrology in the University of Cambridge. New York, The Macmillan Company. 1909. Pp. 383, with 112 diagrams and 2 plates.

This volume by Mr. Harker, which presents the substance of a course of lectures delivered at the University of Cambridge, is not a textbook of petrography but treats in a general way of igneous action and igneous rocks in their relation to the structure of the earth's crust, and of the constitution of igneous magmas considered as complex solutions. In the latter portion of the work an exposition is given of numerous and often rather recondite researches into the physico-chemical relations of natural magmas and artificial slags which have been carried out in recent years by Vogt and others.

With respect to the question of the ultimate source of igneous action the author adopts an attitude which is frankly agnostic.

> The nebular hypothesis in Laplace's form, if not discredited, has at least been shown to involve great difficulties to which no answer is yet forthcoming; the meteoric hypothesis, resting from the first on a more precarious basis, is involved practically in the same damaging criticism; and the planetesimal theory has as yet scarcely emerged from the tentative stage.

After considering the relation of igneous action to crustal movements and pointing out that while there has been a rough periodicity in times of activity and repose, there is nothing to support the opinion that there has been a secular waning of igneous action, the geographical distribution of the younger igneous rocks and the question of cycles of igneous activity are discussed. It is shown that the differences in composition of the lavas emitted from neighboring vents, as well as the very unequal heights to which such lavas rise, prove that they can not draw directly from a common source. Each volcanic center must possess its own proper reservoir of lava, but we

must conclude that the local reservoir of an individual volcano is supplied by drafts from some much larger body of rock magma with which it is from time to time in communication. The various types of igneous intrusion are then considered, especial attention being paid to the numerous varieties of laccolitic and bathylitic intrusion. The important question of petrographical provinces and the mutual relations of associated igneous rocks are discussed at length. While recognizing many local and subordinate petrographical provinces, Mr. Harker distinguishes two petrographical regions of the first order of magnitude, an Atlantic and a Pacific region, the two being separated in America by the line of the Andes and Cordillera folding. The former region is characterized by a prevalence of magmas rich in alkalis, while in the magmas of the latter, lime and magnesia are relatively more abundant. The mutual relations of the magmas in a number of well-known igneous areas within these great petrographical regions is then considered and is illustrated by the aid of variation diagrams.

A very interesting and valuable portion of the book is that in which the physical chemistry of rock magmas and the laws which govern their crystallization is considered. In this results of the recent researches of Vogt, Miers, Day, Doelter and others are presented and critically discussed. The structures of igneous rocks are also considered in the light of recent work in the field of physical chemistry. Thus in hypabyssal porphyritic rocks, the phenocrysts often represent the excess over eutectic proportions and the ground mass the quasi eutectic residuum, while in the volcanic rocks the distinction is obscured by the effects of the discontinuous change of physical conditions at the time of extrusion. Micrographic intergrowths, corona, spherulitic and variolitic structures are explained in the light of the laws of crystallization as elucidated by recent studies in physical chemistry.

The function of mineralizers in rock magmas and the formation of certain minerals through their agency is then discussed, leading to the consideration of the active rôle of the volatile constituents, which on the crystallization of the rock enter upon a new phase of activity, partly of a destructive kind to which Bunson applied the term *pneumatolitic*. Then follows the consideration of the metasomatic changes developed in certain rocks when penetrated by igneous intrusions, more especially the phenomenon termed "granitization" by the French geologists.

The very important question of magmatic differentiation in its various phases is then considered, together with the allied question of hybridism in igneous rocks to which Harker has recently made such important contributions as the result of his studies in the western islands of Scotland.

The last chapter deals with the question of the classification of igneous rocks. The "quantitative system" is adversely criticized and the opinion is expressed that a satisfactory classification can not be expected until our knowledge in the domain of petrogenesis is much more extended than it is at present.

The work traverses a portion of the field of geological knowledge which is not covered by our ordinary text-books, although many of the questions discussed are also treated of in the first volume of Professor Iddings's work on "Igneous Rocks," which has just appeared. It is well and clearly written and will repay a careful perusal by all interested in the modern developments of the science of geology.

McGILL UNIVERSITY FRANK D. ADAMS

Croisière Océanographique accomplie a bord de la Belgica dans la Mer du Grönland, 1905. DUC D'ORLÉANS. Bruxelles, 1907. 4to, 573 pp., 80 plates and charts.

In June, 1905, the Duke of Orleans, having in view a study of the Greenland Sea, sailed from Tromsö, Norway, in the well-known steamer *Belgica*, commanded by A. de Gerlache de Gomery, accompanied by an effective staff. The season being too early for navigation on the Greenland coast the course of the expedition was laid first to the northward by Bear Island, the west and north coasts of Spitzbergen, and then as closely as opportunity permitted skirted the compact southward

extending Arctic pack ice in the hope of finding a passage toward the eastern shore of Greenland through some break in this impassable barrier. Nearly seven degrees of southing were traversed before the *Belgica* could be headed to the westward and, amongst the broken floe ice between the pack ice and the Greenland coast, again struggle to the northward. Under these circumstances a latitude of about 78° 16′ was attained, when the ship retraced her course, leaving the broken ice at a point nearly west of Jan Mayen and thence proceeding to the westward of Iceland, touching at Reykjavik, and so homeward.

Among the special objects of the cruise was the extension and confirmation of Nansen's observations and theories in regard to the conformation of the sea bottom, the currents off the east coast of Greenland, the distribution of marine animal life in the plankton and on the surface of the sea, and the inter-relations of Arctic and North Atlantic waters mingling in the Greenland Sea.

The scientific results are detailed in this truly magnificent volume, in which, of the printer's and cartographer's art, nothing has been spared in the endeavor to approach perfection.

Geographically the more interesting results were the latitude attained by the vessel, a considerable distance further than previous navigators on this dangerous coast; the discovery of a number of new islands off the coast of Greenland; and of a submarine moraine, about forty miles broad-off the Greenland coast and parallel with it, which received the name of Belgica Bank.

Space would not suffice to analyze in detail the work accomplished, but a summary of the contents will enable those interested to form a general idea of the results.

A summary, with synoptical charts of the meteorological conditions during the cruise, is given by Dan La Cour. O. B. Böggild contributes a memoir on the submarine sediments and their distribution, with notes on the submarine moraine before referred to and the continental rocks collected. Ostenfeld, C. Jensen, Ferdinandsen, Winge and Deichmann Branth discuss the phanerogams, mosses, fungi and lichens obtained. Helland-Hansen and Koefoed discuss the hydrography in a division of 220 pages luxuriously illustrated by maps and sections, and more than 100 pages are given to a study of the plankton by Koefoed and others. C. Hartlaub contributes a memoir on the medusæ, and Koefoed one on the fishes with fine illustrations of numerous larval forms. J. Grieg describes the invertebrates collected, first on the coast of Spitsbergen and, secondly, from the Greenland Sea, with the assistance of several other naturalists who have determined the species of special groups. Some observations follow on the food of the walrus, bearded seal, *Tringa striata,* and the tom cod. The volume closes with tables of the dredging stations, an enumeration of the scientific staff of the expedition, and a full table of contents; but curiously enough, no index.

This splendid volume, with its wealth of carefully conducted observations, will form a permanent monument to the liberality and good sense of the noble patron of the expedition and a happy contrast to the barren exploits of unscientific pole seekers with which from time to time the daily press concerns itself.

Wm. H. Dall

SPECIAL ARTICLES

PRELIMINARY NOTE ON THE CHROMOSOMES IN THE OOGENESIS, FERTILIZATION AND CLEAVAGE OF CERTAIN HEMIPTERA

In the recent work on the spermatogenesis of the Hemiptera heteroptera it has been shown that in the members of some families of this group, notably the Coreidæ, the spermatogonia have an odd number of chromosomes, one of the latter being the unpaired idiochromosome or "accessory" chromosome. Owing to the fact that this chromosome passes undivided to one pole of the spindle in one of the maturation mitoses while the others divide equally in both, two classes of spermatozoa are formed in equal numbers, one class having the idiochromosome, the other lacking it. The oogonia have been shown to have an even number of chromosomes, there being two equal

in size in place of the unpaired element of the spermatogonia. It has been assumed that in the maturation of the eggs all the chromosomes divide in both divisions, giving to each matured egg a group of chromosomes similar in all respects to that borne by the class of spermatozoa having the idiochromosome. In short, while the dimorphism of the spermatozoa has been shown to be a fact, the similarity of the eggs has rested upon inference only. It has been assumed further that if an egg is fertilized by a spermatozoon bearing the idiochromosome an embryo will be produced whose nuclei all have an even number of chromosomes similar in all respects to the oogonial groups, but if fertilized by a spermatozoon lacking that chromosome, the resulting embryonic nuclei will all have an odd number of chromosomes similar to the spermatogonial groups. The former class of embryos accordingly will be females, the latter males.

It seemed advisable to the writer to examine the oogenesis, fertilization and cleavage of the coreid family and determine if possible whether there is a basis of fact for these assumptions. With this end in view, sections of the eggs of *Archimerus, Anasa, Chelinidea* and *Protenor* were made, some before laying, but chiefly at intervals after laying. Although some difficulties of technique were encountered, fairly good series were obtained. The results are as follows:

The number of oogonial chromosomes in *Archimerus* is 16, in *Anasa* 22, and in *Protenor* 14. In the first polar (oocyte) division, these numbers are reduced to 8, 11 and 7, respectively. The chromosomes exhibit the same number and size relations as in the first spermatocytes except that the idiochromosome is here a bivalent, having resulted in all probability from the synapsis of two oogonial chromosomes. In *Protenor* the idiochromosome-bivalent can be readily identified by its size. In *Archimerus* all the chromosomes divide in both polar (oocyte) divisions and it is probable that the same is true for *Anasa* and *Protenor,* though all stages of maturation were not obtained in these two forms. As a result of maturation all the eggs are of one kind with regard to their chromatin-content, and further the female pronucleus contains a group of chromosomes similar in number and size relations to that of a spermatozoon bearing the idiochromosome. At fertilization the reduced groups in the male and female pronuclei are again distinguishable just before they enter the first cleavage spindle.

In the cleavage and early blastoderm nuclei of *Archimerus, Anasa, Chelinidea* and *Protenor,* the chromosomes can be readily counted, and show the same numbers and size relations as in the gonads, though, as a whole, somewhat more elongated. Two types of embryos are found, one having an odd, and the other an even number of chromosomes, these numbers being respectively the same as occur in the spermatogonia and oogonia. Accordingly, the former are males, the latter females. Thus in *Archimerus* the embryos have either 15 or 16 chromosomes, in *Anasa* and *Chelinidea* 21 or 22, in *Protenor* 13 or 14. In short the sex of an embryo may be determined by counting its chromosomes.

The results in general complete the history of the idiochromosome ("accessory" chromosome) and its mate, showing their behavior in the maturation of the egg and their presence, either singly or together, in the embryonic (somatic) nuclei. They also lend additional support to the theory of chromosome-individuality and to the recent theories of sex-production based upon cytological studies.

C. V. MORRILL

COLLEGE OF MEDICINE,
SYRACUSE UNIVERSITY

SOCIETIES AND ACADEMIES

THE AMERICAN PHYSICAL SOCIETY

THE regular Thanksgiving meeting of the Physical Society was held in the new physical laboratory of the University of Illinois, Urbana, Ill., on Saturday, November 27, 1909. The meeting was well attended, practically all the universities of the middle west, as well as several in the east, being represented. President Henry Crew presided. The following papers were presented:

"Preparation and Properties of the Heusler Alloys," by A. A. Knowlton.

"Hysteresis Tests of Heusler Alloys," by A. A. Knowlton and O. G. Clifford.

"The Magnetic Properties of the Heusler Alloys," by E. B. Stephenson.

"The Effect of Temperature on the Magnetic Properties of Electrolytic Iron," by Earle M. Terry.

"The Point Discharge in Air for Pressures Greater than Atmospheric," by O. A. Gage.

"On the Mechanical Equivalent of Heat by a Porous Plug Method," by J. R. Roebuck. (Read by title.)

"The Elastic Properties of Platinum-iridium Wire," by Karl E. Guthe.

"An Apparatus for Measuring Sound," by F. R. Watson.

"Polarization of Cadmium Cells," by R. R. Ramsey.

"A Method for Determining the Optical Constants of Metals Applicable to Measurements in the Infra-red," by L. R. Ingersoll.

"The Absolute Values of the Moments of Elementary Magnets," by Jakob Kunz.

"An Apparatus for Studying Moment of Inertia," by C. M. Smith. (Read by title.)

"Some Curious Phenomena Observed in Connection with Melde's Experiment," by J. S. Stokes.

"'Porous Plug' and 'Free Expansion' Effects under Varying Pressure," by A. G. Worthing.

"The Absorption of X-rays an Additative Property," by R. A. Millikan and E. J. Moore.

"A Comparison of the Echelon and Diffraction Gratings," by H. B. Lemon.

"The Value of e by Wilson's Method," by A. Begeman.

"The Flow of Energy in an Interference Field," by Max Mason.

"The Stark Effect with Canal Rays," by G. S. Fulcher.

Ernest Merritt,
Secretary

THE GEOLOGICAL SOCIETY OF WASHINGTON

At the 222d meeting of the society, held at the George Washington University, on Wednesday evening, November 10, 1909, Mr. Waldemar Lindgren offered an informal communication regarding the discovery of a selenium mineral in the gold-quartz ores of the Republic district, Washington State. The veins, which have yielded several million dollars in gold, are contained in Tertiary andesitic rocks and tuffs. The vein matter is quartz, chalcedony and opal deposited in concentric crusts. "Adularia, in considerable amount, also occurs in the gangue." Ore minerals and particularly native gold are rarely visible in the gangue and the ores have proved very difficult to treat. In rich ores slight, black streaks indicate the presence of metallic minerals and in a few places, in the Republic mine, a well-defined black or dark gray mineral forms crusts a few millimeters in thickness. This material is exceedingly rich in gold, but contains no free metal. It consists mainly of an antimonial tetrahedrite associated with specks of chalcopyrite. A partial analysis by Dr. Palmer, of the U. S. Geological Survey, showed no tellurium, but the presence of about one per cent. of selenium, which in all probability is combined with the gold. This interesting result places the Republic veins in the rare class of Tertiary selenide veins, of which Tonopah is the only known representative in the United States. "From descriptions, one of the few deposits of this kind, outside of the United States, is that of Radjang Lebong in Sumatra." No doubt the difficulties which have been experienced in the treatment of these ores are attributable to the presence of selenium compounds. Further metallographic investigations are now in progress to determine the exact character of the selenide.

Regular Program

Characteristics of some Ore Deposits of Southern Humboldt County, Nevada: F. L. Ransome.

A large proportion of the deposits of southern Humboldt County consist of silver ores carrying varying minor quantities of gold. These ores are prevailingly antimonial, the silver being combined chiefly in tetrahedrite or jamesonite. They generally contain in addition a little galena (probably argentiferous) and sphalerite, with of course some pyrite. The gangue is quartz, and as a rule the sulphides are subordinate to the gangue and are rather finely disseminated through it. Argentite and other rich silver-bearing minerals may occur in the upper parts of some of these deposits.

The deposits that owe their value chiefly to gold are those at Seven Troughs and at Chafey. Those at Seven Troughs are in Tertiary volcanic rocks; those at Chafey are in Mesozoic volcanic and sedimentary rocks, probably Triassic.

Like the gold deposits, the copper deposits of the region fall into two classes. One of these is exemplified by the deposits southwest of Boyer's ranch in Tertiary andesite, and by those at Red Butte, which are in igneous rocks doubtfully regarded as of Tertiary age. The deposits at Coppereid and Adelaide, on the other hand, are in calcareous sedimentary rocks, probably belonging to the Triassic. They have the mineralogic characteristics of contact metamorphic deposits. Gar-

net, chalcopyrite, pyrrhotite, sphalerite and pyrite are common to both localities. Axinite, fluorite, epidote and specularite occur in the contact zone at Coppereid, but were not noted at Adelaide. At the latter place the altered limestone contains vesuvianite, diopside and orthoclase.

The antimony and quicksilver deposits, with the exception of some stibnite at Seven Troughs, are all, so far as is known, in Triassic or Jurassic rocks, and are supposedly of the same age as the antimonial silver-gold ores. No facts are known, however, that rule out a Tertiary age for some of these deposits.

The nickel and cobalt deposits in Cottonwood Canyon consist of sulpharsenites of nickel (gersdorffite in part), tetrahedrite and some compound of cobalt with sulphur, arsenic or antimony, with the various oxidation products of these minerals. The ores fill small fissures in much altered andesite or andesite breccia cut by diorite, and may be genetically related to the intrusion of the latter rock.

The southern portion of Humboldt County is part of a metallogenetic province characterized chiefly by the prevalence of antimonial ores of silver with numerous and widely scattered deposits of stibnite and cinnabar. There are in addition some deposits of gold-silver, copper and nickel-cobalt ores. Ore deposition probably began immediately after the intrusion of the Triassic and Jurassic sediments in late Mesozoic time by a granodioritic magma, comparable with that which invaded the rocks of the Sierra Nevada at the same period and continued into the Tertiary. The known Tertiary deposits are essentially gold-silver ores and copper ores, but it is possible that some of the other types are also Tertiary.

Refractive Index of Canada Balsam: F. C. CALKINS.

A very convenient and constantly utilized aid to the determination of minerals in thin section being a comparison of their refractive indices with that of Canada balsam, it is obviously important to know as definitely as possible how widely the refringence of balsam in good slides is likely to vary. The published statements regarding this matter, however, are meager and contradictory, and their experimental basis appears in no case to have been recorded. The following experiments were carried out for the purpose of determining the approximate mean and extremes of the refractive index of the balsam in the slides made for the U. S. Geological Survey.

First, the refractive index of balsam (η) was compared with ω of quartz (1.544) in 300 slides from one to eight years old. It was found that η exceeded ω in only one case out of one hundred, except where the cover-glass was sprung away; where η was greater than 1.544 the excess was extremely small and the balsam was noticeably yellow.

The lowest value observed was between γ and β of nearly pure albite, about $1.535 \pm .002$.

Mr. W. T. Schaller supplemented these observations by measurements with an Abbe refractometer on blank preparations representing the condition of the balsam in normal, in undercooked and in overcooked preparations. The extremes found by Mr. Schaller were 1.535 and 1.543, the mean of eleven measurements 1.5393. The refractive index of one sample of highly fluid uncooked balsam was found to be 1.524.

It therefore appears that the mean refractive index of Canada balsam in good petrographic slides is about 1.54, and that it rarely is less than 1.535 or more than 1.545.

Paleozoic Erosion Channels: E. O. ULRICH.

Fossil erosion channels and caverns afford a valuable proof of the repeated emergence of the sea bottom, they being mostly of sub-aerial origin.

Channels and caverns of Pennsylvanian, Mississippian and late Devonian age have been described and figured, but earlier examples, though abundant and of unmistakable origin, have remained but imperfectly known.

Erosion channels may be divided into three classes: superficial, submarine and subterranean. The first class embraces all sub-aerial channels formed by running water, including tidal overflows. The second class embraces all channels produced by currents scouring the sea bottom; these are very rare as strong currents manifestly seldom occur in the shallower epicontinental seas. The third class includes solution cavities and caverns formed in limestones and dolomites by the action of acidulated surface waters.

As illustrating superficial erosion, may be mentioned channels in the Trenton at Trenton Falls, New York, which were probably in the nature of "guts" on ancient tidal flats. Concomitant with the formation of these channels gravitational slumping occurred, resulting in their partial filling with much distorted strata. A doubtful instance of submarine erosion is found in the Fern Glen (Kinderhook) in northern Arkansas, with an overlap of Boone chert. To this same class probably belongs an intraformational erosion surface exhibited by the Lowville near Watertown, N. Y. Most

striking examples of solution cavities and caverns occur in the flanks of the Ozark uplift in Missouri. Some of the caverns are excavated in the pre-Ordovician Jefferson City dolomite, others in Niagara limestone; the filling in either case consisting chiefly of late Devonian and early Mississippian sandstones. Others again occur in late Devonian limestone, while several instances in Ordovician limestone of Lowville and Stones River age were found filled with later Ordovician sediments.

PHILIP S. SMITH,
Secretary

THE 223d meeting of the society was held at the George Washington University on Wednesday evening, November 24, 1909.

Regular Program

Rock Glaciers in Alaska: STEPHEN R. CAPPS.

The rock glaciers, a hitherto undescribed feature, occur in large numbers and in exceptionally perfect development in the area covered by the Nizina Special Map, Copper River region, Alaska. They all head in glacial cirques and extend from these down into the valleys, varying in width from one tenth to three fifths miles, and in length from one half to two and one half miles. The surface slopes range from 9° to 18°. In slopes, shape and surface markings they bear a striking resemblance to glaciers. In the upper portions longitudinal ridges and furrows are conspicuous, while toward the lower ends the ridges become concentric, parallel with the borders of the lower ends of the flows. A few of the rock glaciers actually grade into true glaciers at their upper ends. Most of them, however, show no ice or snow on the surface, the fragmentary rock of which they are composed extending up to the cirque walls above.

All the rock glaciers examined were found to be cemented with interstitial ice, which filled the openings to within a few feet of the surface at their upper ends, but was farther from the surface in the lower ends. This ice has imparted to the mass of rock waste a kind of glacial movement which is thought to be still in operation in many of the flows. The typical rock glaciers differ from true glaciers in that they head in cirques in which there are no perennial snows; in the purely interstitial character of the ice; and in their ability to endure in climatic conditions in which ordinary glaciers can not exist.

Canyon de Chelly, Arizona: M. R. CAMPBELL.

(No abstract.)

Geological Observations in Iceland: FRED. EUGENE WRIGHT.

Geologic mapping in Iceland is still in the reconnaisance stage. Most of its geologic features are as yet known only in a general way. Like the Faroe Islands, Iceland consists almost wholly of volcanic rocks (basalt) and associated tuffs and breccias. Thorrodsen has shown that the earliest rocks now exposed are probably of early Miocene age and that volcanic activity has characterized the island since its uplift in early Miocene or late Eocene. Among its most striking structural features is block faulting, but interest in the island centers chiefly in its volcanic and glacial phenomena. Among the former are explosion craters, lava cone craters, crater series along faults, fissure eruptions, secondary craters, etc., in model-like development and on a scale far surpassing that of any other country. Among the latter are the erosional effects of both continental and valley glaciers, especially prominent in north Iceland where the basalt formation is nearly flat-lying and homogeneous in character. The valleys exhibit: U-cross-sections, hanging side valleys, steepening of grade toward valley head with tendency toward cirque development, glacial grooves and markings along valley sides, truncation and alignment of spurs, etc., between tributary valleys, low cigar-shaped spurs at junction of larger tributary valleys attenuated by overriding of glaciers confluent at acute angles. In a country covered with an ice-cap, the surface of the ice sheet is an important plane of reference which in its physiographic effect is often similar to that of a water surface, as sea-level, toward which all exposed land surface tends to be reduced. The mountains and rock cliffs emergent above the ice-sheet undergo rapid changes in temperature with accompanying shattering due to expansion of included moisture in freezing, and tend to break down rapidly and to be reduced to the level of the ice surface. Whatever the nature of the erosional activities going on below the surface of the ice cap, the ultimate result will be a truncation of the mountains at a common level, strongly resembling in appearance an uplifted and dissected peneplain.

FRANCOIS E. MATTHES,
Secretary

AT the 224th meeting of the society, held on December 8, 1909, Mr. Arthur Keith presented the following paper: "The Status of Geologic Names."

The student of stratigraphy in anything except

the most limited way at once encounters the question of names. In the pioneer stage of geology a name is required for each new unit described, since exact correlation with existing names is usually impossible. This is less true of the second stage of geologic work, where information is accumulated and names multiplied. American geology has now advanced to the third or selective stage, where many correlations are certain, and preliminary names are gradually passing.

The most oppressive fact to the student is the flood of names. About 3,500 have now been used in the United States and Alaska, and to them nearly 100 new ones are added yearly. The labor of digesting these seems almost prohibitive to stratigraphic progress. A single name is applied to two or three different units, and for the same unit there may be five or six different names.

The complexity is increased by poor definitions and shifting limits of the units. Limited attempts have been made to reduce and correlate. Individuals and state surveys have done their part locally, the U. S. Geological Survey has issued correlation bulletins covering the United States, and a general committee representing the chief American organizations has recently been formed to make recommendations on names.

The chief attack on the chaos is now being made by the committee on geologic names in the United States Survey. All names used in papers issued by the survey or its members are considered by this committee. Exact definitions and type localities are required for new names, and the use and correlation of old names considered. Comparative harmony is thus secured, the number of new names is kept down, poor uses are rejected and useless names abandoned. The committee takes acount of priority, clearness of definition and locality, and the usage of each term, no one feature being supreme. Various catalogues of the committee cover its own action, the full list of names in use, the names in each system, in each state, and the various columnar sections published in each state. All of these are complete to date except the last, on which work is steadily proceeding, and are available for general consultation. These are leading to a comprehensive correlation of the formations of the United States.

The underlying motive of all this work is utility. A name is given to a stratigraphic unit for convenience in referring to it. If the definition is exact and the use consistent, the idea conveyed will be precise. If it is not precise it is not scientific, and should be avoided as obscuring the mental image. If a geologic name for a unit could be extended over the whole country, the case would be ideal and the image would be called up with the least effort. Many formations and names can be carried far and wide, and in that degree will the alphabet of geology be simplified. To sift and tie together the loose mass of names will cause hardships, but they will be lost sight of in the enormous gain in ease and clearness. The present incubus of names is something to be shaken off at the earliest moment.

At the close of Mr. Keith's address the seventeenth annual meeting of the society was held for the purpose of electing officers, and the following officers were elected for the ensuing year:

President—M. R. Campbell.

Vice-presidents—T. W. Stanton and David White.

Secretaries—Francois E. Matthes and Edson S. Bastin.

Treasurer—C. A. Fisher.

Members at Large of the Council—Geo. H. Ashley, F. B. Van Horn, Geo. W. Stose, A. R. Schultz, W. C. Mendenhall.

PHILIP S. SMITH,
Secretary

THE PHILOSOPHICAL SOCIETY OF WASHINGTON

THE 671st meeting was held in the West Hall of George Washington University on November 20, 1909, President Wead in the chair. Two papers were read:

The First Cruise of the "Carnegie" and her Equipment: Dr. L. A. BAUER, of the Carnegie Institution of Washington.

The Producer Gas Engine on the "Carnegie": Mr. CARL D. SMITH, of the U. S. Geological Survey.

A detailed description was given of the non-magnetic producer gas engine plant installed on the *Carnegie*, and the principles involved in its construction and operation were illustrated by lantern slides. The plant consists essentially of a gas producer and a producer gas engine with the necessary accessories.

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For an account of the success already achieved by this plant and its remarkable economy of fuel consumption, see the abstract of the paper by

Dr. L. A. Bauer on "The First Cruise of the *Carnegie* and her Equipment," which will be printed in SCIENCE.

THE 672d meeting was held in Hubbard Memorial Hall on December 4, 1909, President Wead in the chair. The evening was devoted to addresses commemorative of the life and work of Professor Simon Newcomb. Addresses were made by the following persons:

The Right Hon. James Bryce, ambassador from Great Britain; Professor Milton Updegraff, director, Nautical Almanac; Dr. R. S. Woodward, president of the Carnegie Institution of Washington; Dr. L. O. Howard, chief, Bureau of Entomology, Agricultural Department; Professor E. M. Gallaudet, president, Gallaudet College.

At the close of the addresses the following resolutions were read and adopted:

WHEREAS the Philosophical Society of Washington has been deprived by death of the fellowship of Simon Newcomb, and

WHEREAS he was for thirty-eight years one of its active members and twice served as its president, be it

Resolved that the society record its high appreciation of his phenomenal talents, his preeminent attainments and his scholarly discussion of the many topics which his broad sympathies and varied interests proposed for consideration. And be it further

Resolved that this society unite with the learned societies and institutions of the entire world in testifying to the loss to science and high learning which his death occasioned; and that we hereby convey to the bereaved family assurance of our profound sympathy.

R. L. FARIS,
Secretary

THE SOCIETY FOR EXPERIMENTAL BIOLOGY AND MEDICINE

THE thirty-fifth meeting of the society was held at the College of Physicians and Surgeons, October 20, 1909, with President Lee in the chair.

Members present: Auer, Ewing, Famulener, Foster, Gies, Harris, Hatcher, Hunter, Joseph, Lamar, Lee, Levene, Levin, Meltzer, Mayer, Meyer, Morgan, Morse, Murlin, Norris, Noguchi, Opie, Park, Pearce, Rous, Symmers, Schaffer, Stockard, Van Slyke, Wadsworth, Weil, Wolf, Zinsser.

Scientific Program

Charles R. Stockard: "The Influence of Alcohol and other Anesthetics on Developing Embryos."

Richard Weil: "On the Variation in the Resistance of Human Erythrocytes in Disease to Hemolysins, with Especial Reference to Syphilis."

W. Koch and F. W. Upson: "The Distribution of Sulphur Compounds in Brain Tissue."

Robert L. Benson and H. Gideon Wells: "The Study of Autolysis by Physico-chemical Methods."

A. I. Ringer (by invitation): "Influence of Adrenalin in Phlorhizin Diabetes."

Andrew Hunter: "A Method for the Determination of Small Quantities of Iodine in Organic Material."

Sutherland Simpson and Andrew Hunter: "Relations between the Thyroid and Pituitary Glands."

Peyton Rous: "Parabiosis as a Test for Circulating Antibodies in Cancer."

Jean V. Cooke (by invitation): "The Excretion of Calcium and Magnesium after Parathyroidectomy."

Hideyo Noguchi: "Non-fixation of Complement."

Hideyo Noguchi: "The Fate of So-called Syphilitic Antibody in the Precipitin Reaction."

Thorne M. Carpenter and John R. Murlin: "The Energy Metabolism of Parturient Women."

Alfred G. Mayer: "The Relation between Ciliary and Muscular Movements."

EUGENE L. OPIE,
Secretary

THE AMERICAN CHEMICAL SOCIETY
NORTHEASTERN SECTION

THE ninety-fifth regular meeting of the section was held at the Twentieth Century Club, Boston, on November 26. The annual election of officers took place. Dr. P. A. Levene, of the Rockefeller Institute for Medical Research, in an address on "The Biochemistry of Nucleic Acids," described how the structure of these compounds had been determined by a study of the cleavage products produced by hydrolysis under various conditions.

Dr. H. A. Torrey, of Harvard University, addressed the section on "Alkali-insoluble Phenols. Does structural chemistry explain them?" After having shown that several rather obvious hypotheses as to the relation of structure of certain phenols to their action with alkalies were untenable, the speaker offered the explanation that the unexpected action of these substances might be due to the existence of an equilibrium between a phenol and quinoid form.

K. L. MARK,
Secretary

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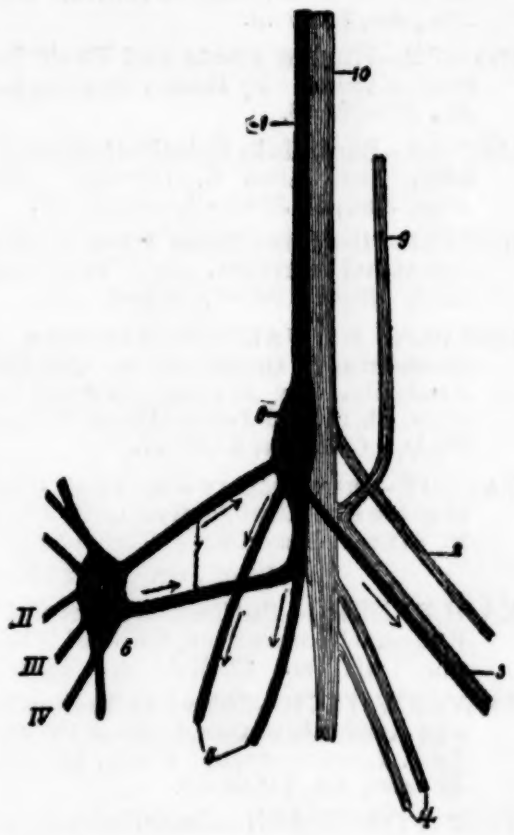

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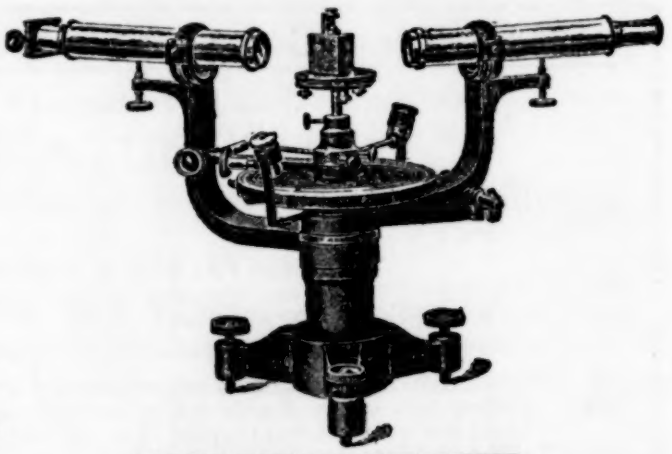

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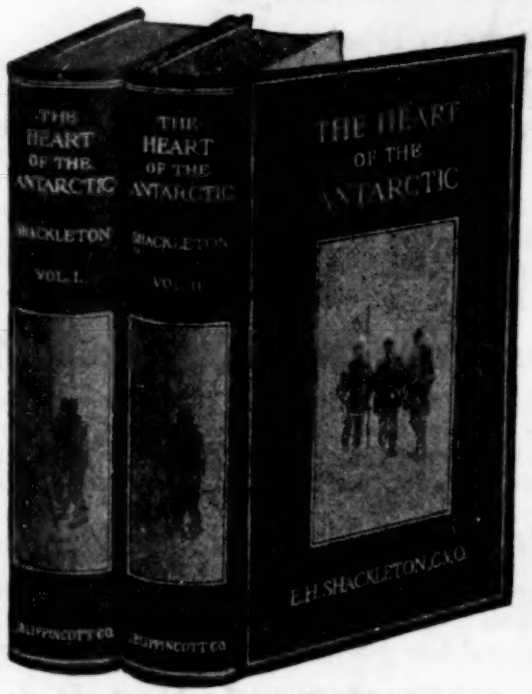

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